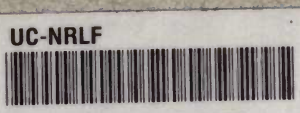


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GUIDE

TO THE

COLLECTIONS OF ROCKS AND FOSSILS

BELONGING TO THE

GEOLOGICAL SURVEY OF IRELAND,

ARRANGED IN ROOM III. E. OF THE MUSEUM OF SCIENCE AND ART, DUBLIN.

BY

A. M'HENRY, M.R.I.A., AND W. W. WATTS, M.A., F.G.S.

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CENTRAL COURT

PLAN OF ARRANGEMENT IN GEOLOGICAL SURVEY ROOM III.E.

(COLLECTION OF IRISH ROCKS AND FOSSILS)

Cases 1 to 41 contain Fossils arranged in Stratigraphical order from left to right.

Cases A to G contain Igneous Rocks.

Cases & pedestals 42 to 53 contain fossils

Cases I to XXXII { Sedimentary Rocks / Foliated Crystalline Rocks

XXXIII Contains miscellaneous rocks

NOTICE

THIS Guide is issued as one of the series of handbooks to Collections deposited in the Science and Art Museum, Dublin. It may be said to supply a real want, and therefore, although the possibility of the collection being removed to a new gallery, at no very distant period, is not out of sight, the necessity for early publication is nevertheless manifest.

V. BALL,
Director, Science and Art Museum,
Dublin.

30th November, 1894.

PREFACE.

THE nucleus of the Collection to which this volume is a Guide, was formed under the supervision of Professor J. Beete Jukes, as Director of the Geological Survey of Ireland. The specimens were fully described by him in an elaborate catalogue, which has long been out of print, and is now difficult to procure.

After his time the collection was considerably increased under the direction of his successor, Professor E. Hull, and within the last few years it has been still further enlarged. Advantage has been taken of its removal to the present Museum of Science and Art to re-arrange it entirely, and illustrate it by means of descriptive labels, diagrams, photographs, drawings and maps. The general scheme of arrangement, combining reference to the great political divisions of the country, together with the petrographical and stratigraphical relations of the specimens, was planned by myself, and has been carried out with much care and success by Messrs. M^{c}Henry and Watts. In order to make the collection still further useful, both to students and the general public, it has been thought desirable to prepare a General Guide which, without being a mere catalogue repeating the descriptions on the labels affixed to the specimens, will form a convenient handbook, not only to the contents of the gallery, but to the general geology of Ireland.

Great care has been taken to preserve what was of permanent value in the original collection, and to fit it into the present arrangement, while at the same time all that is still of importance in Jukes' Catalogue has been incorporated in the labels of the specimens and in the present volume.

Besides a large series of rock-specimens, there is also an important collection of Irish fossils arranged in stratigraphical order. These specimens, as well as the rocks, have been almost entirely collected by the Geological Survey, and are still continually receiving additions. They were originally named by J. W. Salter and W. H. Baily. They comprise also a portion of the famous Portlock Collection, the rest of which, including the type-specimens, is preserved in the Museum of Practical Geology in London.

In the preparation of this Handbook, Mr. M'Henry's great local knowledge of Ireland and of Irish geology has been of use on every page. Having chief charge of the fossil collections, he has superintended the labelling, naming, and re-tableting of the specimens, and has furnished the list of organic remains which were used in drawing up the Palæontological part of this volume. A large number of the rock-specimens in the old series having been collected by him, he has been able to furnish important information regarding them, and the geology of the districts from which they were obtained.

The actual writing of the Handbook has been assigned to Mr. Watts. In addition to the copious materials supplied to him by Mr. M'Henry, he has himself furnished many original details regarding the Petrography. He has been under the necessity of carefully analysing the previous literature of Irish geology. Every possible source of information open to him has been made use of, but in a book of this description it is neither possible nor desirable to load the pages with references to authors. It must suffice to make here a general acknowledgment of indebtedness.

No fresh work on Irish geology can appear without an expression of special gratitude to three great observers—Griffith, Portlock, and Jukes—whose labours as admirable pioneers and leaders so largely aided the advance of geological science in their time.

The most constant and valuable sources of information in the preparation of the following pages have been the maps, memoirs, and other publications of the Geological Survey, including the work of such men as Oldham, Du Noyer, Kinahan, Baily, Kelly, Hull, Wynne, Foote, Hardman, Teall, Sollas, Hatch, and Hyland. Outside the ranks of the Survey much assistance has been obtained from the petrographical and mineralogical writings of Haughton, Scott, Hamilton, Wilkinson, von Lasaulx, Cole, and Joly; from the chemical work of Kane, Apjohn, Sullivan, Tichborne, Galbraith, Reynolds, Mallet, Gages, and O'Reilly; from the field-observations of Buckland and Conybeare, Harkness, Bryce, Weaver, Verschoyle, Harte, Close, Swanston, Callaway, and Praeger; and from the palæontological researches of Huxley, M'Coy, Wright, Lapworth, Tate, Barrois, and Bell.

The proofs of the Petrographical part of this volume have been seen by Mr. Teall and Professor Sollas, and Mr. E. T. Newton has furnished similar assistance in regard to the Palæontological part.

ARCHIBALD GEIKIE,
Director-General of the Geological Survey.

24th November, 1894.

CONTENTS.

CONTENTS

PART I.

INTRODUCTION

THE collection of the Geological Survey is displayed in room No. III. East. It is limited to specimens obtained from Ireland, and consists of two parts—one illustrating the typical *rocks* of the country, the other the *fossils* contained in them. There are likewise exhibited in the gallery, drawings, photographs, maps, and sections, intended to illustrate the sets of specimens and to give an idea of the scenery, economic products, and geological structure of different parts of the country.

The **rock** collection is arranged *geographically*, the products of each of the four Provinces of the country being grouped in close proximity to one another. The cases containing the rocks are the **wall-cases** along the side of the room, lettered A to G; the **upright-cases** placed above the table-cases in the middle of the room, marked with Roman numerals from I. to XXXII.; and one **table-case**, XXXIII., at the N. end of the room. Both numbering and lettering run from the south to the north end of the gallery (*v.* plan, frontispiece.)

The collection of **fossils** is arranged in *stratigraphical* (historical) order, beginning with the earliest known forms of life and passing up to the most recent. It will be found in the **table-cases** in the middle of the room and under the windows, numbered from 1 to 42, and in a few **cases** and on **pedestals** on the west side of the room, numbered 42–53, proceeding also from south to north.

The general order in which the specimens are intended to be studied is from left to right. The *numbering* on the labels of the specimens refers to the registers kept by the Survey, and is not consecutive, but it is convenient to use these numbers in referring to specimens of interest and importance, while the general sequence of remarks and description in this Guide adheres to the order of arrangement just indicated, from case to case, and from left to right.

1. THE ROCKS.

It has been found advisable to arrange the rocks in three broad classes. 1st. Those which result from the cooling of the heated matter of the earth's interior, have come to the surface through volcanic activity, and have been ejected in the form of lavas and ashes, injected into or between other rocks as veins, dykes, or sills,

or thrust in mass into other strata as necks, bosses, or laccolites. These are the **Igneous Rocks** which are for the most part built up of crystalline minerals; they are usually unstratified and unfossiliferous. 2nd. Those which have been made out of the broken fragments of pre-existing rocks, worn from them by wind, weather, and water, and deposited for the most part as sediments on the sea floor. These are the **Fragmental** or **Sedimentary Rocks**, and are for the most part built up of consolidated pebbles, sand, or mud, or of the relics of organisms; they are often fossiliferous, and almost invariably are arranged in beds or strata (bedded or stratified rocks). 3rd. Those which have usually been made by the modification or metamorphism of some other rock, either sedimentary or igneous, by the agency of heat, water, pressure, brought into action by some great earth movement, or by the influence of the intrusion of igneous rocks. For want of any comprehensive name to include the various processes which have contributed towards the formation of such rocks, the term **Foliated Crystalline Rocks** will be used here, and it will include most of the types formerly included under the term Metamorphic rocks. They are built up of crystals which, however, are usually arranged in folia or layers which imitate in general appearance the strata of the sedimentary rocks.

The Rocks of all these types are arranged and described according to the Provinces of Ireland in which they occur. A general notice of the rocks of each Province is followed by a more minute account of its igneous rocks. This description begins on page 15.

The Wall-Cases.—Igneous Rocks.

The igneous rocks are placed in the large wall-cases lettered A to G, beginning at the south end of the room. A study of these cases will give the student a history of volcanic action in Ireland from the earliest times up to the great outbursts which covered the north-eastern counties with vast floods of lava. The igneous rocks from **Leinster** are in cases A and B, those from **Connaught** in C and D, from **Ulster** in E and F, and those from **Munster** in case G. The general grouping is *topographical;* where any marked region of igneous activity can be clearly defined its products are put together, the deeper-seated (Plutonic or Granitic) rocks claiming attention first, next the dykes and sills which may have nearly reached the surface, and lastly the ejected lavas and ashes.

The upper part of these cases is occupied by maps of some of the chief areas illustrated by the specimens below, the sides by drawings, and the bottom of cases A and G by large specimens for which there is not room elsewhere. A few large specimens are also placed in case XXXIII. and some on the pedestals on the west side of the room. The drawers under the wall-cases contain duplicate specimens, or those which cannot be displayed for want of space.

In the arrangement of the igneous rocks the chief basis of classification is chemical composition. Four great groups of these rocks are recognized—the acid, intermediate, basic, and ultra-basic—according to the amount of silica they contain. The acid rocks contain more than 65 per cent. of silica, the intermediate from 55 to 65, the basic from 45 to 55, and the ultra-basic below 45 per cent. Each group is again divided according to the nature of the white minerals (felspars, &c.), and black (ferromagnesian) minerals which it contains; thus *syenite* is distinguished from *diorite* because its most abundant felspar is orthoclase, while that of *diorite* is plagioclase. Each of these smaller groups is further sub-divided according to the state of crystallization of the constituent minerals in the rocks—a condition which has depended largely on the depth at which the material consolidated, some portions having crystallized deep down below the earth's surface (Plutonic rocks); others near or at the surface, as in lava flows and superficial intrusions (Volcanic rocks). By this classification the plutonic, coarsely crystalline, *granites*, for example, which probably solidified at great depths, are separated from the micro-crystalline or cryptocrystalline *rhyolites*, and from the glassy *pitchstones* which are connected with volcanic action and have often been erupted above ground.

The Upright Table-Cases.—Other Rocks.

These cases will be found attached to the upper part of the table-cases, and they contain the rest of the rock collection. The plan of the cases divides the gallery into nine bays, and these are so arranged that in the second bay the reader would be surrounded entirely by the sedimentary rocks from Leinster, in the third by the foliated crystalline rocks from the same Province, in the fourth by sediments from Connaught, followed by the foliated rocks, and so on. In the treatment of each case the two lower shelves are taken together, and the whole space between two vertical bars treated as one compartment.

Sedimentary Rocks.—These are arranged in *stratigraphical* (historical) order; the oldest system is placed first and on the left, and is followed towards the right by newer and newer systems. The sub-division of systems is, when practicable, carried as far as that expressed on the survey maps. Within each sub-division such as the Carboniferous Slate, or Lower Carboniferous Limestone, and also where the systems have not at present been divided, the grouping of specimens is according to districts, ranging generally from N. to S. and from E. to W. in each Province.

For want of a more convenient method of classification two or three different types of rocks are placed together as a third series in the remaining upright table-cases, VII.—X., XV.—XVIII., XXIII.—XXVI.; they have, however, these important characters in common, that they are now for the most part **crystalline rocks** which are **foliated**, that is, have their component

minerals arranged in layers, and that they have been profoundly modified or **metamorphosed** so as to lose many of the characters they originally possessed. This is due either to the heat caused by the intrusion of some local mass of igneous rock as in the case of the schists in the borders of the great Leinster granite, or to some more wide-reaching cause which has brought heat, pressure, and water to bear in producing great chemical and mechanical changes in regions that have for the most part been the focus of intense earth-movement during the formation of mountain chains, as in the rocks of Donegal in cases XXIII.–XXVI. Some of these rocks have originally been sedimentary, some igneous, but chiefly intimate mixtures of the two types; they are now, however, converted into quartzites, marbles, granulites, gneisses, and schists.

The top rows of these cases are occupied by large specimens of rocks belonging to all classes, but placed here for want of space elsewhere or in order to enable them to be more clearly seen. They are, as a general rule, allied either in rock type or locality to the specimens placed immediately beneath.

The upright-cases I., II., and XXXII. are temporarily reserved for the display of **recently acquired specimens** or those of immediate or local interest.

2. THE FOSSILS.

The Flat Table-Cases.

This collection is classified according to the chief divisions or *Systems* of the geological record; thus all the representatives of the life of Lower Silurian time will be found together; on the left of them those from the Cambrian rocks, and on the right those from the Upper Silurian System. Within each system the fossils are arranged according to their zoological affinities, the whole of the Graptolites of the system being followed by the Corals, these by the Crinoids, Cystids, Trilobites, and so on in order.

Although it has not hitherto been found possible to sub-divide the groups of fossils (or *faunas*) more minutely, the label of each specimen bears its precise locality and also its exact position in the geological sequence when that has been accurately ascertained; members of the same sub-division of the animal kingdom derived from the same locality are placed as near together as circumstances will allow. The aim of the arrangement is thus twofold: firstly, to illustrate the life history of Ireland, and secondly, to keep the fossils from one locality together, so as to make the specimens available for reference and comparison by students.

A general description of the anatomy of fossil plants and animals is given on page 95 of the Guide, followed by a fuller account of the more noteworthy fossils collected in Ireland, dealt with in stratigraphical order and in the order in which they will be met with on passing along the cases. The *numbers* used refer to the cases, to the pedestals on which individual specimens stand, or to a few framed slabs placed round the walls of the gallery.

3. THE ILLUSTRATIONS.

On the end walls of the gallery and those opposite the windows will be found a series of drawings made by Mr. G. V. Du Noyer, late of the Geological Survey, and a few by Mr. W. H. Baily. Some of these have been transferred from the Royal College of Science, the rest from the office of the Survey. They are taken from different parts of the country and are intended to illustrate the characteristic scenery resulting from different kinds of rocks and rock-structures. There are represented igneous rocks, tilted and contorted sediments, moraines, eskers, boulder-clays, erratic and perched boulders, mines, and such other geological features as admit of pictorial treatment. Associated with these and also on the opposite walls are a number of large and small photographs in some cases illustrating features similar to those in the Du Noyer drawings, kindly taken and given to the Survey by Dr. Tempest Anderson and numerous members of the Belfast Naturalists' Field Club, the last having been collected for the museum by Miss M. K. Andrews. In the wall-cases above the specimens will be seen the one-inch survey maps illustrating some special portions of the Province from which some of the rocks exhibited below have been obtained, and at the side of the cases are smaller sketches, chiefly by Sir A. Geikie and Mr. M'Henry, taken from the published memoirs of the Survey. A few typical, horizontal and vertical sections of interesting or economically important lines of country are also framed and displayed on the walls. The *numbering* of these illustrations begins at the south end of the gallery and runs consecutively round the west, north, and east sides. A descriptive list of all the illustrations will be found at the end of the Guide, page 128, and references to them are given in brackets throughout the Handbook, those marked D. referring to drawings, P. to photographs, M. to maps, and S. to sections and plans.

PART II.

THE ROCKS.

1.—LEINSTER.

I. GENERAL ACCOUNT OF THE ROCKS.

The oldest known rocks in the Province of Leinster belong to the Cambrian system. They rise to the surface in rugged moorland hills with a type of scenery made so familiar by Howth and Bray Head. The mountains, round which the southern part of Leinster is grouped, are carved out of a mass of granite, intrusive

into Lower Silurian rocks, at a date later than the Lower Silurian, but earlier than the Carboniferous, Period. The mountains are rounded moorlands, with abrupt sides, sometimes reaching an altitude of 3,000 feet, and not seldom crowned with the tors of rock so characteristic of granite areas. This barren upland gives way at its edges to picturesque, wooded, ravines and hills, of more graceful outline, and with broken and irregular summits, where the Lower Silurian strata with their richly varied petrological character, and their interbedded and intrusive igneous rocks, rest on the granite. Where the Cambrian rocks are brought to the surface, rugged hills again occur, often varied and irregular in trend owing to the lenticular shape of the hard, ridge-making, quartzites and grits. Like a carpet the Carboniferous Limestones succeed, filling up all hollows and levelling out the central plain of the country which is only broken where the more ancient Silurian and Old Red Systems protrude in isolated inliers, like Slieve Bloom and Slieve-naman, or where some coal-bearing or other newer rocks rest on the surface of the Limestone, forming terraced escarpments, or the shelving flanks of the coal basins of Kilkenny and Carlow or Louth.

The following table will give an idea of the general succession of sedimentary and igneous rocks in this Province. Like all other tables in this guide it is given in descending order:—

Systems.	Series.	Igneous Rocks.
7. Pleistocene, . . .	—	—
6. Trias, ...	—	Intrusive Rocks.
5. Carboniferous, . . .	Coal Measures, ...	Interbedded Rocks?
	Millstone Grit, ...	
	Yoredale Series, ...	
	Carboniferous Limestone, . .	
	Lower Carboniferous Sandstone,	
4. Old Red Sandstone, .	—	—
3. Upper Silurian, . .	—	Intrusive Rocks?
2. Lower Silurian, . .	—	Intrusive and Interbedded Rocks.
1. Cambrian, . . .	—	Intrusive Rocks.

In the table each set of intrusive rocks is placed opposite the latest sedimentary rocks which it is known to penetrate in that Province.

CASE III.—THE CAMBRIAN SYSTEM.

The only known Cambrian rocks in Ireland occur in this Province. They come to the surface in three isolated regions, at **Howth**, about **Bray**, and in **Wexford.** (Map A; Sect. 51). The types of rocks are very much the same in all these areas and vary only in the proportion of their different ingredients; green and purple *grits* (711, 912, 1227, 3476), generally much hardened, *slates* of similar colours, hardened and cleaved (842, 1222, 2662, 3440), are interstratified with great lenticular patches of *quartzite* (1220), and *quartz-rock.* On the whole the coarse-grained rocks predominate towards the north, and on Howth there are bands of *conglomerate* (845, 6) and quartzite (3441, 2), with well rounded "pebbles," and even slaty beds containing included fragments of slate and other rocks (3443). The "pebbles" consist of quartzite, lydian stone, grits, and slates, that is the same types of rocks as occur *in situ* on the hill, and it has been suggested that they are due to the breaking up of the beds soon after their formation by volcanic action. However, no volcanic fragments have hitherto been found amongst them, and this is in favour of an alternative explanation, that they are due to the action of earth-movement in breaking up the beds after their formation. The remarkable breccia of angular fragments which is exposed along the north shore of Howth (847), along the line of contact with the Carboniferous rocks, is certainly due to this agency.

The quartzites, when examined microscopically, still show their original fragmental structure, although in the field they behave almost as though they were intrusive masses. The slates and many of the grits do not split parallel to their bedding planes but at a high angle to them, the intense lateral pressure having compressed them into a smaller space. This result has been attained by the arrangement of the particles with their longer dimensions at right angles to the stress. This gives a new 'grain' to the rocks along which they 'cleave' so as to form slates and slabby fissile grits; unfortunately, however, the structure is rarely perfect enough to form really good roofing slates. Still, slates for this purpose are quarried at the Devil's Glen in Wicklow and elsewhere. (1222, 3, 4, 712).

Some of the specimens exhibited show that the cleavage is much more perfect in fine-grained slaty rocks than in grits, while in the latter rocks the structure is more nearly perpendicular to the bedding planes than in the former (1224, 713). Not infrequently new minerals, such as sericite, have been freely developed in the rock (1226). The rocks are also broken by other divisional planes, generally in two sets at right angles to one another and to the bedding. This enables the stone to be quarried into great blocks with approximately rectangular surfaces. The quartzites are traversed by innumerable, less regular, shrinkage fissures or joints, which cause the rock masses to shiver down into small sharp edged fragments and splinters under the

disintegrating action of the frost wedge. This type of denudation imparts conical outlines to such hills as are built of quartzite, like the Great and Little Sugarloaf near Bray.

The only organic remains hitherto obtained from the Irish Cambrian strata belong to lowly forms of life, and are more minutely described at page 109. The fossil called *Oldhamia* (2663) is of doubtful but probably organic origin, and three species have been described from the localities above mentioned. Tracks and burrows of worms called *Arenicolites* and *Histioderma* have also been found. Professor Sollas has recorded the occurrence of microscopic bodies from the slates of Howth, which have the appearance of being the relics of minute animals called *Radiolaria*, and more recently he has described an obscure but probably organic structure under the name of *Pucksia M'Henryi*.

On account of the folding of these rocks no accurate estimate of their thickness has yet been made, but there is very little doubt that it is considerable. The masses at Howth and Bray are pierced by dykes of porphyrite allied to that of Lambay Island, by diabases, and at Greystones by picrite. The only igneous mass of importance in the Wexford Cambrian rocks is a dyke of porphyrite at Cahore Point. All these are intrusive and will be fully described in the sequel (pp. 35 & 36); no contemporaneous volcanic rocks are known.

Case IV.—The Silurian System.

There are three great areas of Silurian rocks in Leinster which occupy a large extent of country, and a few minor exposures; the *Dundalk* and *Slane* region in Louth and Meath, the *Dyleek* and *Balbriggan* area, and the great district flanking the Leinster granite which sweeps from *Rathfarnham* to *Castledermot* on the west, and from *Killiney* to *New Ross* on the east.

The rocks are mostly hard, grey, green, and purple, *slates and grits*, but as they show considerable lithological variation it will be better to deal with each important area by itself. Fossils are not common, but where they do occur are marine forms, like Trilobites, Graptolites, and Shells. The rocks were formed in a sea whose shore line has not been well made out except where the Lower Silurian rocks rest unconformably on the Cambrian rocks, indicating that for part of the time the latter must have formed islands or peninsulas in the Silurian sea.

Economically the rocks are of importance in this Province as they form the "country-rock" in which veins of the ores of lead, silver, iron, copper, and other metals have been mined. These veins stretch in a broad belt from Croghan Kinshela to Deputy's Pass, and are also found in other isolated localities in Dublin and Wicklow (Sec. 11). It is also highly probable that the source from which the alluvial gold of Wicklow was originally derived may have been these rocks where acted upon by intrusions of granite and basic igneous rocks as near

Croghan Kinshela. Slates are also occasionally quarried in Silurian rocks as at Carnew and in Wexford, while hone-stones are derived from them in Kilkenny. It is hopeless at present to attempt to form an estimate of the thickness of the Lower and Upper Silurian Systems, until they have been broken up into more minute sub-divisions so that the complicated structure of the ground can be unravelled; any estimate founded on the dip of the rocks is open to serious errors owing to the repetition of the same series again and again by folds and faults, and to the injection of great thicknesses of igneous rock. The igneous rocks are in part contemporaneous lavas or ashes, but are chiefly intrusions of a date later than the Silurian Period (*v.* page 33). Needless to say the intrusion of so much molten material has often effected important modifications in the original sedimentary structures of the rock, and the metamorphism has frequently obliterated their structure entirely and produced masses of foliated crystalline rocks; these are dealt with on page 39.

North of the Province.—The southern part of the Cavan area is just inside the Province of Leinster, but, as the bulk of the rocks and those which give the key to their structure are in Ulster, it will be better to describe them in that place (page 61). There are, however, certain *grits* associated with important beds of *conglomerate* (1443, 6), such as those of Granard, which it will be well to notice at once. The pebbles are of granite, some of them derived from the mass of Crossdoney (*v.* page 76), associated with lydite, grits, and fragments of a chert lithologically like that recently found by the Survey *in situ* in Tyrone; these fragments, however, yield Radiolaria like the cherts found in the Lower Silurian rocks of South Scotland and on the N.E. coast of Co. Down, at Donaghadee. These conglomerates are likely to be of Upper Silurian age, but on the maps they have not yet been distinguished from the Lower division of that System.

The Area of Louth and Meath (Map B).—Silurian rocks stretch away to the south and south-west of Dundalk, Dunany Point, and Clogher Head, from Louth into Meath. Recent researches by Mr. Clark have shown that at least four important horizons can be recognized in these rocks by means of the Graptolites and other fossils which they contain; the Llandeilo and Caradoc Series of the Lower Silurian System and the Llandovery and Tarannon Series of the Upper Silurian; thus, in descending order:—

Tarannon Series,	Salterstown, near Dunany Point.
Llandovery Series,	Mooretown, Kellystown House, W. of Tullyallen.
Caradoc-Bala Series,	Collon, Slane, and Grangegeeth.
Llandeilo Series,	S. and S.E. of Ardee, near Newtown Fortescue, and Harlinstown.

From this it will be seen that the Lower and Upper Silurian rocks are closely interfolded together, so that the work of disentangling them on the maps over large areas will be one of time. About Dundalk and Dunany Point the rocks are hard, greenish *grits* and *slates*, much indurated. Near Slane dark, carbonaceous *shales* (1286) are interbedded with sheets of andesitic lava and ash, which probably represent the great Arenig or Lower Llandeilo eruptions of North Wales and the English lakes, as a Graptolitic fauna of that date has been found in the associated sedimentary rocks. It is, however, not impossible that some of the volcanic rocks may belong to the period of the Bala or Caradoc eruptions, as Bala fossils are found in close proximity. These are followed by grey quartzose and felspathic *grits* and *shales* of Bala or Llandovery age. There are many intrusive sheets (or sills), dykes of diabase, and lamprophyre (or mica-traps), and intrusive bosses of augite-syenite in the Slane district (*v.* page 36). Passing along the strike of these rocks towards Clogher Head to the north-east, coarse and fine indurated *grits* occur, possibly of Llandovery date, which are saturated with dykes of lamprophyre and diabase, and are frequently much metamorphosed by them (3518, 9, 3546). The igneous rocks of these areas are placed with the other igneous rocks of the Province in case B, and are described on page 37.

Duleek and Balbriggan Area (Map B).—The lowest rocks of this area are the lavas and ashes of Bellewstown, which are banded with *clay-slates* (718, 716), such as are quarried at Balbriggan, and black *shales* (914), full of *Didymograptus Murchisoni*, and hence are of Lower Llandeilo or Upper Arenig age. It is not a little interesting that the composition of the igneous rocks of this date in Ireland corresponds very closely with that of rocks of similar date in England and Wales. In this region again Upper Silurian rocks bearing *Monograptus* are closely interfolded with those of Lower Silurian age. On Lambay Island and at Portraine there are a few bands of *limestone* from which many fossils, chiefly Corals, Brachiopods, Trilobites, and a few Graptolites of Silurian genera have been obtained. On Lambay Island occurs a *conglomerate* (672, 684, 685) containing pebbles of Silurian limestone embedded in a matrix from which fossils of the same age can be extracted; this has probably originated from the breaking up of a newly-formed limestone by the volcanic action which was rife at intervals during this period. The rocks are intruded upon by sills and dykes of porphyrite, one of which is the beautiful ornamental "porphyry" of Lambay, with its green porphyritic crystals of felspar embedded in a dark-green matrix. Intrusive rocks of other types, such as diabase and lamprophyres, are also found at Duleek (*v.* page 37.) At the Chair of Kildare are found the well-known pink and grey, crystalline, fossiliferous, *limestones*, here interbedded with red and dark-grey fissile *shales* several hundred feet thick, penetrated by igneous rocks of the

Lambay type, and covered by *grits* recalling those of Meath and Cavan. A large series of fossils from these rocks will be found in cases 3 to 13.

Flanks of the Leinster Granite (Maps A and B).—Proceeding further south the rocks become more uniform and finer-grained, *slates* (717), green, purple (1238), and black in colour with occasional fine *grits* (1234) and *limestones* (877) taking the place of coarse grits and sandstones. These begin to undergo changes within a mile of the outcrop of the granite, and the metamorphism increases as the junction plane is approached (*v.* cases VII. and VIII.), so that eventually the slates become highly micaceous, crystals of andalusite, and at times garnets make their appearance, and eventually the rock passes into a mica schist. Much of the beautiful wooded scenery of Wicklow, which affords such a welcome and striking relief to the rounded granite moorlands, is due to the varied character and metamorphism of these rocks. Throughout their whole extent the sediments are interbedded with ashes and lavas (2664) and seamed with dykes, sills, and other intrusions of an exceedingly varied set of rocks, granites and microgranites, felsites, diorites, dolerites, epidiorites, and picrites. These igneous rocks are often crushed so much that new minerals and structures have been formed in them, making felsitic and hornblendic schists, while the sediments are frequently cleaved and contorted (738, 9), the puckering sometimes passing down to the minutest and even most microscopic scale (1230, 1); all these changes indicate clearly the intense lateral pressure to which they have been subjected. Fossils are abundant in these rocks in Wicklow and Wexford, and prove them to be of Lower Silurian age. It is interesting to note that they occur nearly always, in fact almost solely, in the ash beds. Indeed this is true of the Silurian rocks throughout Ireland, as no fossils but Graptolites are found in any abundance except in association with contemporaneous igneous rocks.

The Silurian rocks of Slieve-naman, Slieve Bloom, and Mount Mellick are coarse greywacke *grits* (1593) and hard, close *slates* (1595), more or less cleaved, from which, however, in Leinster no fossils have yet been recovered.

Mr. Kinahan has recognised three divisions of the Silurian System in Wexford. The lowest is a *Dark Shale Series* comparable with the Llandeilo of Wales, and containing three seams of *anthracite* and some *graphite*. This is followed by his *Ballymoney Series* of red and purple *shales*, *grits* (878), and *ashes* (715), with eruptive rocks and Caradoc-Bala fossils, and this in turn is succeeded by a series almost devoid of grits, but with *Grey* and *Green Slates*, useful for building purposes. Possibly this last series may represent the higher part of the Caradoc or even part of the Upper Silurian System.

Case IV.—The Old Red Sandstone.

This System of rocks occupies a comparatively small area in Leinster, generally a mere fringe to the Silurian tracts, but becomes of greater importance towards the South of the Province. The rocks appear to have been formed in fresh-water lakes, some of which were continuous with those of Scotland. They are of uniform and somewhat monotonous character, red, purple, brown, and white *sandstones*, with intercalations of similar coloured *shales* and *conglomerates* in which pebbles of vein quartz predominate. Two or three small tracts in Longford answer to this description (682), and are here unconformable to the Carboniferous rocks above and the Silurian beneath. On Lambay, at Donabate (sec. 51) and Portraine, small patches of pink *sandstone* and *conglomerate*, not more than 300 feet thick, have been mapped as Old Red Sandstone; salmon-coloured *sandstones*, puce *conglomerates*, and purplish *shales* fill the hollows of denuded Silurian rocks to the north of the Chair of Kildare, while there are red quartzose *conglomerates* near Newcastle and Rathcoole; these rocks are little more than a local base to the Carboniferous System.

Omitting the small inliers, all but covered up with newer rocks, which occur to the south and south-east of Athlone, where the rock is unconformable to both Silurian and Carboniferous Systems, the Old Red Sandstone begins to assume real importance round the Slieve Bloom and Devil's Bit Mountains. A basal *breccia* is followed by white, dull reddish, purple, or speckled *sandstones* and *grits* (1597, 8), frequently containing plant-remains (724), and amounting to 800 or 900 feet in thickness. Equally thick and important are the same rocks in Kilkenny where an upper division of yellow *sandstone* (The Kiltorcan Beds) is of interest because it has yielded fossils including plants like *Adiantites* and *Sphenopteris* (725), a freshwater mussel *Anodonta Jukesii*, Crustacea, and Fish (*v.* frame 45). In Wexford a purplish *grit* and *conglomerate* has been mapped as Old Red Sandstone. This formation is of little economic importance. It forms the border tract of hilly ground between the mountainous Silurian country and the flat plain of Carboniferous Limestone

Cases V. and VI.—Carboniferous System.

(Map B; D. 18).—Much of the area of Leinster is occupied by rocks belonging to this System and chiefly by the lower part of the great Limestone Series which, however, is here and there covered by the higher divisions of the System, or by a capping of the highest Carboniferous rocks in Meath and in the coalfield of Kilkenny. The divisions usually recognisable are the following, but it is not always that all of them can be identified, as some thin out or have been removed by excessive denudation, while

it is sometimes impossible to draw lines between the different divisions of the Carboniferous Limestone.

8. *Middle Coal Measures.*
7. *Lower Coal Measures.*
6. *Millstone Grit.*
5. *Yoredale Series.*
4. *Upper Carboniferous Limestone.*
3. *Middle* „ „
2. *Lower* „ „
1. *Lower Limestone Shale or Basement Beds.*

The lowest rocks contain marine forms of life and indicate the entrance of the sea into the Old Red Sandstone lakes, while the succeeding masses of limestone indicate that the sea deepened considerably and swarmed with Shells like *Producta* and *Spirifera*, with Corals like *Lithostrotion*, *Zaphrentis*, and *Michelinia*, which sometimes built veritable reefs, or with an immense abundance of Crinoids, like *Actinocrinus*, *Poteriocrinus*, &c., whose remains build up great thicknesses of calcareous rock. Layers of shale and beds of impure limestone show that powerful rivers and currents could still bring sediment from the not very far-distant land, and eventually the whole basin became shallower and covered by river deltas in which, at first under marine conditions and later under fluviatile conditions, the Yoredale Series, Millstone Grit, and Coal Measures were deposited. Judging by what is left of the Measures it does not appear that the conditions were ever very favourable for the growth of coal; the seams are few in number and poor in quality, and the persistent denudation of subsequent ages during which Ireland stood above water has deprived her of what little coal she had.

The famous black marbles with white shells from Kilkenny and Carlow are quarried in the Carboniferous Limestone, which also yields road metal and excellent lime, both ordinary and hydraulic, the latter when it is not very pure but loaded with fine particles of clay or silica. The crystalline limestones furnish good but rough building blocks, the darker, argillaceous limestones, though widely used, are less satisfactory; the crinoidal limestones are used for building and also for marble. The grits and sandstones provide freestones much used locally for building and flagging, and, when rough and gritty for millstones, while the Coal Measures give coal, iron, fire-clays, and clays useful for pottery. Occasionally small quantities of lead and zinc are found in the veins which penetrate the limestone, while beds of hæmatite and even clay-ironstone occur sometimes in the same rock.

In Leinster the limestone area is usually flat or gently undulating ground largely covered by bog and devoid, except in a few places, of scarps or any important physical features; the Yoredale

Beds and Millstone Grit, by the alternation of hard grits or limestones with soft shales, form parallel valleys and ridges or escarpments, such as those seen round the Leinster coal-field, prominent amongst which is the abrupt scarp of the Millstone Grit; the Coal Measures occur in areas which are basins in physical contour as well as in geological structure.

The *thickness* of the various members depends on local circumstances, and differs so much from point to point that any estimate of total thickness would not be of much use. Where fully developed, however, the System can hardly be less than 6,000 feet thick. The only igneous rocks are the intrusive dykes, almost certainly of Tertiary date, found in Louth and Meath, and the interesting series of lavas and ashes about Phillipstown which may be compared with the rocks of Limerick on the one hand and with those of Derbyshire on the other (*v.* page 38).

The Lower Limestone Shale or Lower Carboniferous Sandstone.—This division is usually thin and unimportant in Leinster, the subsidence of the land and its lakes beneath the Carboniferous Sea having been somewhat sudden and rapid. There are beds of yellow *sandstone* in County Meath, occasionally traversed by basalt dykes belonging to the great Tertiary volcanic group, and fine grained siliceous *grits* (1449) in Longford. In the South, in Wexford, the Carboniferous System is heralded by beds of barely consolidated *conglomerate* (721, 2) made of pebbles derived from the granitic, silurian, and cambrian rocks on which they rest. But in the central region, wherever the lie of the rocks allows their base to be seen, it consists of dark calcareous *shale* with bands of thin flaggy *limestone* (1600) which increase in number and importance in the higher part of the Series. Sandstones are rare in this central tract where the whole thickness rarely exceeds 100–200 feet.

The Lower Carboniferous Limestone.—The lowest division of the great Limestone Series is the foundation of the Central Plain of Ireland and its wide-spread bogs. The rock is usually grey, or bluish-grey in colour (729), often fossiliferous (1299, 1602), and more or less crystalline in texture (1602). A few beds of laminated micaceous *sandstone* occur in Louth and Meath (1298), and many *sand-beds* in Wexford where the limestone is itself sandy (852, 864, 733, 915), but in the central tract the limestone is pure and frequently displays oolitic structure as at Edenderry (732), near to which the rock is dove-coloured and made up of globular bodies consisting of radiating crystals of calcite (carbonate of lime), generally accreted round some foreign substance such as a chip of shell, a crinoid stem, or a grain of sand (731, 3477). In West Meath a grey limestone, which takes a high polish, is quarried as a *marble*. In Dublin, King's County, and Carlow portions of the rock have been transformed into *dolomite*, that is limestone containing a variable but frequently large percentage of carbonate of magnesia. In Queen's County the limestone contains bands of *chert*,

When this Limestone is not separated from the older rocks on which it rests by any intervening deposit, its lowest beds, as at Skerries, contain pebbles of these older rocks. The thickness of this Stage is about 1,000 feet in the centre of the Province, and about 200 feet more in Kilkenny.

The Middle Carboniferous Limestone, or "Calp" as it is sometimes termed, is usually a dark-coloured or black *limestone*, shaly or flaggy, and interbedded with dark *shales* and even occasional *sandstone* beds. The individual limestone bands are not constant in character or thickness for any considerable distance. About Philipstown there is a volcanic area dating back to Carboniferous times, bands of basic ash containing fragments of limestone, and intrusive limburgites and basalts, occurring in the middle limestone, which is penetrated by coarser grained basic rocks. The igneous rocks are apparently covered by the highest member of the Limestone series. In Queen's County a bed of yellowish or brown crystalline *dolomite* occurs at the summit of the Series. Bands of *chert*, usually grey in colour, are of not infrequent occurrence (935, 675). Fossils are not so common in this group as in the beds above and below, and where they occur are usually large *Productæ* and Corals. The thickness of the Stage varies from 600 to 800 feet, but there is a general tendency for it to become thinner towards the west.

The Upper Carboniferous Limestone is not always separated from the Middle, this being the case when the former division loses its purity and becomes more intermingled with sedimentary material, so as to approach the calp in composition. This is the case in the Dublin district (Map B., Sec. 51), where both stages consist of grey thin bedded *limestone* with black *shale* partings; often it is darker in colour and much veined with calcite (1302), and sometimes magnesian limestones occur; these are frequently cavernous, as though the rock had shrunk in volume during its metamorphism, and crystals of bitter spar are often found lining the cavities (728). Those beds which are not far from the granite near Dublin Bay, contain lumps derived from it, often as much as 18 inches in diameter, together with fragments of schists and other rocks from the flanking Silurian chain (726,730). A special series of these has been collected by the Director of the Museum and placed in the neighbouring room (IV, East), where he has illustrated them by a set of similar stones carried great distances from the shore in modern times by such agencies as sea-weed, floating wood, ground ice, and other forms of floating ice.

In its characteristic aspect the Upper Limestone recalls the lower stage; it is a light grey (1315), shelly (851), *limestone*, usually sub-crystalline in texture (2667), and often oolitic (1608, 1619, 1621). When this structure is present, as in West Meath and King's County, the rock forms an admirable building stone. In Kilkenny, where the Stage is 1,500 feet in thickness, and also

elsewhere, there are abundant beds of *chert*, which are sometimes 30 or 40 feet in thickness, and vary from dark grey (674) to black (727) in colour (*v.* D. 22). The passage from limestone to chert is quite gradual, the rock becoming more and more siliceous until at last it consists of almost pure silica with a splintery or conchoidal fracture and horny or resinous lustre. From the abundance of spicules and skeletons of sponges displayed in microscopic sections of the chert it has been concluded that the silica was derived from this source and that after partial solution it was redeposited and aggregated in those portions of the limestone which were already exceptionally rich in these fossils. The limestone is often made up wholly of fragmental crinoidal stems, and is usually rich in fossils. *Dolomites* occur everywhere; they are white or yellowish grey in colour, finely crystalline, and exhibit no signs of lamination or bedding; they occur as beds, as plates and masses related in position to the joints traversing the rock, and even in a dyke-like form running uninterruptedly for many miles. It has doubtless been formed by the passage, through the joints and beds of the rock, of water bearing magnesian salts in solution, which has replaced pure carbonate of lime by a double carbonate of lime and magnesia.

The Yoredale Beds, or "Shale Series" as they are sometimes designated on the maps, mark the close of the limestone-forming period. They are generally shaly in character, especially in the lower part, the few bands of *limestone* being thin, black, and impure; occasional bands of *iron-ore* and even worthless *coal-seams* occur in the Series.

Towards the North, in Meath and Louth, there are 300 or 400 feet of dark *shales* and thin *limestones* underlying the Millstone grit, and in the eastern counties a few outliers (Sec. 51) formerly mapped as coal measures, would now probably be classed with this Series. The rocks consist of 500 feet or so of hard, dark, splintery *shales* interstratified in some places with thin *grits* and *flagstones*. Under the Kilkenny coalfield the black slaty *shales* and splintery *mudstones* frequently weather out into spheroids. The series here is about 500 feet in thickness and contains hard grey *sandstones* with a few beds of *flagstone* (853), and some *ironstone* seams of poor quality (1243).

The Millstone grit, or "Flagstone Series," is a persistent group of hard, thick, *sandstones*, *grits*, and *flags*, occasionally yielding plant-remains but rarely other fossils, 500 feet thick at the north of the Leinster coalfield but thinning away towards the south and east. In Louth the series of coarse, massive, micaceous quartzose *grits* and *conglomerates* under the coal measures is about 200 feet thick, while in the south of Meath *grits* and *shales* with thin *coal-seams* (1317, 676) rest on the Yoredale beds already described.

The Lower Coal Measures, or "Gannister Beds" of Louth contain quartzose *grits* (1336) and beds of *sandstone* (1333) which are

frequently coloured purple or red, probably by the agency of water penetrating from the Permian or Triassic rocks above them. Those of Meath are fine grained, white, brown, or mottled *Sandstones* with at least one seam of *coal* 1 foot thick. The measures of the Kilkenny coalfield (Secs. 46 and 50) are hard, grey, and mottled brownish grits penetrated by stigmarian rootlets, *fireclays*, and *brickclays*, *shales* (854), and occasional bands of *ironstone*. There are 4 seams of *coal*, varying from 3 feet to 6 inches in thickness. A few marine fossils are found in this division (Sec. 51).

In the Middle Coal Measures of the same region there are 6 seams of *coal*, the four highest of which are now worked out. These are thicker and vary from 5 feet to 1 foot in thickness, and their fossils are related to modern freshwater types. A large collection of Amphibia has been obtained from the Jarrow seam, the lowest member of the stage. The interbedded measures are much the same as those of the lower Stage (855). The whole of the coal measures is about 1,600 feet in thickness (Sec. 51).

CASE VI.—THE TRIASSIC SYSTEM.

(Map B.) In Leinster there are no Permian rocks, so that the Trias is the only system occupying the enormous gap between the Carboniferous period and the deposits of the Pleistocene period which succeed: even this System is very poorly represented by a portion only of its two Series the Bunter and Keuper, and this deposit is not found further South than the northern part of Meath.

The Carboniferous rocks had been folded and their surface eroded before the Bunter beds were laid down in the lakes formed on the denuded surface of Carboniferous and older rocks.

The Bunter is represented by a soft light-red, flesh-coloured, or pink, *sandstone* bright in colour and well laminated.

The Keuper.—The Bunter is followed, in the neighbourhood of Kingscourt by the Keuper Series, thin bedded, laminated, brownish *sandstones* with bands of grey and red *shale;* then comes a considerable, but unknown, thickness of red and grey shaly *marl* containing beds of *gypsum* (1330) which have been at times worked in this neighbourhood. The Keuper *clays* are used for brick-making.

CASE VI.—THE TERTIARY GROUP.

Resting on the "solid" rocks of Ireland there are usually found "superficial" deposits laid down by the agency of the sea or freshwater, by the action of ice, or even by some cause capable of forming deposits in the air. It is extremely difficult to classify these satisfactorily and even in many cases to ascertain their

relative age, as so many different agencies were at work in different localities—the sea on the shore, the lake or river inland, and the glacier on the mountains. Again, during oscillation of level a homogeneous deposit might travel inland or out to sea and appear to be a continuous layer, while, as a matter of fact, one end of it must, of necessity, be very much older than the other. Roughly, the deposits may be classed as **pre-glacial, glacial,** and **post-glacial** with reference to the great extension of ice over the country in the glacial period.

CASE VI.—Pre-glacial Rocks.

Pipe Clays.—To the N.W. of Roscrea a small patch of *pipeclay* occurs. It is similar to that of Caher, in Tipperary, of which a description will be found on page 88.

"Manure Gravels" of Wexford.—This series of deposits underlies the boulder-clay in Wexford. The lowest beds are fine, clean, sharp *sands*, without stones or shells; these are followed by beds of finely comminuted *shell-sand*, in which ninety species of shells have been found; the sections are completed by fine *gravel* with shells, which are occasionally perfect but are generally waterworn and broken. The majority of the shells are of species which are still living on the Irish shores, but a certain proportion are such as inhabit the Mediterranean and southern seas, while a few are extinct. They indicate a warmer climate than the present; judging by the resemblance of the fauna to that of the Pliocene beds of St. Erth in Cornwall, the gravels must be of Pliocene date, but more recent than the St. Erth beds. Mr. A. Bell, who has investigated the deposits, concludes that the Wexford gravels are succeeded in date by those of Ballybrack; the latter again by those of the Wicklow mountains, to be immediately described.

CASE VI.—The Pleistocene System.

The Lower Boulder-Clay.—This deposit presents us with the record of the great Ice Age in Ireland. Although different observers rarely agree upon any one theory to account for its origin all are agreed that it has been made by ice in some form, whether ice-sheets on land, shore-ice, or icebergs. The deposit, known as boulder-clay, is a stiff tough *clay*, usually red, brown, or blue in colour, and made up of material denuded from local rocks. It is generally unstratified but occasionally stratified and is full of rounded pebbles or angular blocks of rock, often of very large size, set pell-mell in the clay without any sort of arrangement (D. 35). These blocks are often polished and smoothed, striated and grooved, as though they had been held firm in the grip of moving ice and slowly dragged over the surface of rock (1244), and as the rock on which the boulder-clay rests is usually polished and grooved in a similar way it is clear that the

stones have been polished by the rock bed over which the glacier has moved. The direction of the grooving, together with the direction in which blocks of stone have been carried, show the direction of ice movement to have been on the whole from N.W. to S.E. in Leinster, though this direction is disturbed where mountain masses served as barriers or independent centres of ice dispersion. The main snow-shed which gave birth to the ice of, at any rate, this part of Ireland is supposed to have stretched from Belfast to Galway Bay. The clay is irregularly and somewhat capriciously distributed but has a tendency to occur in ridges or *drumlins* whose long axes coincide with the direction of ice flow, or in sheets filling up valleys and lapping against the sides of the mountains, even to a height of 1400 feet. Amongst the far travelled boulders found in the Leinster boulder-clay may be mentioned Antrim chalk and flints, granites from Mourne and Newry, rhyolites from Forkhill, and riebeckite-microgranite like that found at Ailsa Craig. The boulder-clay passes up into the succeeding deposits of sand and gravel by the alternation of seams of clay with beds of gravel. Contortions, irregular junctions, and the dropping of sand into pipe-like hollows of the boulder-clay may perhaps be accounted for by the melting of blocks of ice contained in the latter. Fossil shells are occasionally to be found in the boulder-clay, sometimes whole and unbroken but more usually fragmental and even polished and striated like the rest of the derived blocks in the clay.

The Sands and Gravels, sometimes called the "Corn Gravel," "Limestone-Gravel or-Drift," from the profusion of limestone blocks in it, sometimes the "Interglacial Sands," are seen in such sections as that of Ballybrack and Killiney to rest on the Lower Boulder-Clay, and sometimes to be covered by the Upper Boulder-Clay. The deposit consists of irregularly bedded *sands* and *gravels* sometimes containing large boulders, which would indicate that ice-action of some sort had not entirely ceased. Many of the boulders and pebbles consist of limestone, but other local rocks are present like cambrian sandstones, quartzite, schist, lydites, and igneous rocks. Sollas and Praeger have described pebbles of the subjacent boulder-clay in the gravels. They contain shells, sometimes in abundance (*v.* p. 119), which are mostly of northern types but seem to indicate a slightly warmer climate than those found in similar gravels at Moel Tryfaen in North Wales. The gravels with their shells are found at Ballyedmonduff, Caldbeck Castle, and elsewhere, to extend upwards on the flanks of the Wicklow mountains to such heights as 1,250 and 1,300 feet, and it is very difficult to account for them in such situations without supposing a great submergence to at least this extent. Occasionally the gravels are converted into a solid rock by the deposit of salts of lime or iron.

The Upper Boulder-clay is of much the same character as the Lower, but, probably owing to extensive denudation, is

somewhat rarely met with. It is a reddish, stiff, *clay* with boulders, and seams of sand and silt. In Carlow it is 90 feet thick in places.

The Esker Gravels.—These deposits have sometimes been considered the equivalent of the mid-glacial sands and gravels, but are more generally thought to be rather later in date. It is of course quite possible that they may be of several different dates, and probably all so-called eskers may not have originated in the same way. The eskers are long mounds, frequently of considerable height, devious in direction and extending over flat country, along valleys, or even at times across the older physical features of a district. In the centre of Ireland, extending from Connaught into Leinster, they are numerous and gigantic, being sometimes 50 or 60 feet high, resting on a base 100 to 200 feet wide, and as much as twenty-five miles long. A group of these eskers at Coney Cairn is represented in Mr. Du Noyer's drawings Nos. 37 and 38. The mounds are made up of fine *gravel* with a stratification which generally follows the outline of the mound. Shells are occasionally met with but are distinctly rare, a thing which might possibly be attributable to the ease with which water percolates through the gravel. No perfectly satisfactory theory has yet been advanced to explain the origin of the eskers. While some observers believe them to have originated from deposition under the influence of marine currents as sand bars and banks during submergence, Professor Sollas and others regard them as the deposit formed by the superficial drainage of the ice sheet, the rivers which traverse the surface or flow at the bottom of the ice and which, carrying mud, sand, and gravel with them, must deposit it under the ice, or on it to be afterwards let down as the ice melts. One thing is certain, that the glaciation had not ceased when the eskers were formed, for their surfaces are often strewn with erratic blocks of stone which may be of considerable size. Numerous erratic blocks are found scattered over the surface of the ground in Leinster and the other Provinces, not necessarily in direct connexion with any glacial deposit, and they may belong to any part of the glacial period (*v.* D. 36). The esker gravels of Kildare are sometimes cemented into a conglomerate (737).

Local Moraines also occur in the Province. They have clearly been formed near the close of the glacial period by ice fields and local glacier systems of small extent occupying the chief mountain areas, such as the Carlingford and Wicklow mountains. Upper and Lower Lough Bray are dammed by such moraines, and a beautiful group of local moraines has been described and figured by Kinahan on Mount Leinster.

Raised Beaches.—These, consisting of material similar to a modern beach but at a level beyond the reach of the highest tides of the present day, are found stretching along the coast line in various places. The neck which unites Howth to the mainland is one of

them, and relics of a similar beach, cemented into a conglomerate by aragonite a form of crystalline carbonate of lime, occur along the shore of Dublin Bay by Salthill and Kingstown (790). The **Estuarine Clays** of Clontarf which contain marine shells are believed by Mr. Praeger to be a deeper-water deposit of the same age. As the rivers, during a period of submergence such as the terraces and clays indicate, would necessarily flow at a higher level than at present, it is highly probable the **high level gravel** terraces which fringe these rivers may be of about this date; such gravels are sometimes converted into solid stone in Wexford. From an economical point of view the old gravel terraces and alluvia of the rivers which drain the northern slopes of Croghan Kinshela are very important, as it is from them that the alluvial gold of Wicklow has been obtained, and hitherto all attempts to trace this gold to its source have been fruitless. Its association with fragments of heavy minerals such as magnetite, hæmatite, tinstone, copper pyrites, galena, topaz, and garnets seems to show that it has been worn down from veins in igneous and metamorphic rocks.

Peatbogs. Over the interior of the Province these are of great extent and value. They are often of great depth, and frequently rest on beds of blue, shelly *marl*, containing freshwater and lacustrine shells, similar to those in existence at the present day. Mr. Clement Reid finds that some of the *Megaceros* marls are mainly composed of *Chara*, with other water plants. Other **modern deposits** are *blown sands*, *river alluvia*, and *intakes* or deposits formed by the filling up of lakes, low valleys, or arms of the sea by warping, the deposit of mud carried down by rivers in flood; in limestone districts masses of *travertine* or carbonate of lime are sometimes deposited by the calcareous springs (735).

2.—THE IGNEOUS ROCKS OF LEINSTER.

Case A.—Dublin, Wicklow, and Wexford.

(Maps A. and B.; Sec. 50).—One of the grandest areas of Igneous rock in Ireland is that of the Leinster granite and its flanking masses, which sweep from the south side of Dublin Bay to the boundary of Waterford, forming a chain of "lumpy, woolpack, hills" sometimes attaining a height of over 3,000 feet. The main chain is a great mass of *Granite* 70 miles long and 20 miles broad at its widest part. It is a true *Granite*, coarse in grain, and distinguished by its large crystals of muscovite, a white potash mica (a monoclinic unisilicate of alumina and potash). Biotite and muscovite were the first of the so-called essential minerals to crystallize, and they were followed by plagioclase felspars which vary from albite (triclinic unisilicate of soda) to oligoclase (triclinic unisilicate of soda and lime), these by quartz (hexagonal silica), while the last constituent to take the solid form was generally microcline (a triclinic potash felspar, or unisilicate of alumina and potash, allied to orthoclase in com-

position). A large series of coarse and fine-grained types, obtained from all parts of the Province, is exhibited. Occasionally biotite (a magnesian mica) is present in considerable quantity (1917, 1926, 1928, 1931), rarely to the entire exclusion of the muscovite (1927, 2030) when the rock must be called *granitite*. Porphyritic felspar is well shown in the large specimen 1216. Many other minerals are present as minute inclusions; zircon (tetragonal unisilicate of zirconia), titanite or sphene (monoclinic subsilicate and titanate of lime), apatite (hexagonal phosphate of lime), and rutile (tetragonal oxide of titanium); tourmaline or schorl (a hexagonal complex subsilicate of soda, potash, magnesia, lime, and alumina) is present at times (1945) either in the body of the rock or coating its joints (1946, 7).

Other minerals mentioned by Mr. R. H. Scott are beryl (hexagonal bisilicate of alumina and beryllia), fluor (cubic fluoride of lime), orthite (monoclinic unisilicate of lime, iron, alumina, and ceria), iron and copper pyrites (cubic sulphides of these metals), and galena (cubic sulphide of lead), with cordierite or iolite (orthorhombic unisilicate of alumina, magnesia, and lime) discovered by Joly. At Tinahely large crystals of spodumene (monoclinic bisilicate of lithia and alumina) occur, and these are often converted into a pseudomorph which has been named killinite (a hydrous silicate of alumina and lithia) (1951). Veins containing garnets (cubic unisilicates of alumina or iron with lime or magnesia) also occur (1948). When the crystals of the essential minerals are large and the rock forms a coarse *pegmatite*, that is, one in which the quartz is intergrown with the felspar giving rise to the appearance suggestive of Hebrew writing which has caused the rock to be called graphic granite, the muscovite often occurs in plumose masses (1213, 1950) which are very beautiful. The granite has been much used for buildings, and many of the footpaths in Dublin are paved with granite flags. Kaolin or china-clay (silicate of alumina) has been quarried at Baltinglass, where it results from decomposition of the felspar due to the loss of its potash (2676). Ores of iron and manganese have occasionally been found in the granite.

The granite is traversed by veins or dykes of *aplite*, a rock made up of quartz and felspar, with little or no mica; these are well seen on Killiney Hill and in the railway cuttings below it (1952–3, 2678). Where it has undergone intense pressure, and this is especially the case near its margin, it has become foliated; that is, its minerals are arranged in layers. A good example, with layers of mica, is seen in 1956; others are seen in 1935, 1957, and specimens, in which the rock is undistinguishable from a *gneiss*, are found at Graigue-na-managh in Carlow (2685.) Near these are placed a few specimens showing patches of sedimentary rock contained in the granite (1960), or the junction of granite with sediments (D. 21), which are in both cases converted into *mica-schist* (1958, 2679), a rock composed of alternate leaves of quartz and mica (*vide* page 39).

The Leinster granite always contains a considerable percentage of soda as well as potash, and in studying the veins (or apophyses) which it sends out into the surrounding sediments, and the innumerable smaller masses evidently connected with it and derived from the same source, it has been found that the amount of soda gradually increases until it becomes double that of the potash. These rocks have been described by Professors Haughton and Sollas. They are usually so much finer grained than those of the main chain as to deserve to be called *microgranites* (1961, 1981), and they even pass down gradually at their edges and extremities into *quartz-felsites*, in which the larger porphyritic crystals of quartz and felspar, and sometimes mica, are embedded in an amorphous paste (1964, 2688). They are somewhat less acid than those of the main chain, and are frequently rich in biotite (1937, 1944); others of them contain hornblende (monoclinic bisilicate of magnesia, lime, and iron, with alumina) (1968), especially those of Croghan Kinshela (1942), and here the rock often consists of inclusions (segregations?) of dark rock involved in a network of light coloured veins (1979). The striation of the plagioclase felspar is frequently observable in hand specimens of these rocks. They have been injected as sills, for the most part roughly parallel to the bedding of the surrounding sediments, which are much metamorphosed by them, and they are to be found flanking the granite throughout almost its entire extent.

The age of the great granitic group of rocks has not been precisely determined. It is a curious fact that it is not known to come into contact with the Cambrian rocks, although it is intrusive into Lower Silurian rocks; its date is therefore later than the Lower Silurian period, and certainly earlier than the Carboniferous, for fragments broken from it occur in a limestone-conglomerate at the base of the Carboniferous Limestone of Dublin (*vide* page 25). It may therefore be either of Upper Silurian or Old Red Sandstone date, and as the latter period was one of great earth-movement we may reasonably place the date of its irruption in the Old Red Sandstone period.

Parallel with the edge of the chain and outcropping along the strike of the strata are innumerable bands of different varieties of *felsites* (fine grained rocks with the same chemical composition as granite), and other rocks. The bulk of these are lavas which have been poured out and interbedded with the Lower Silurian sediments amongst which they are found. They have been disturbed with them also, and have frequently been crushed, and have acquired a brecciated, flaky, or schistose structure in consequence; examples of all these structures are placed in the next division of the case (1985, 6, 1215, 1991). The felsites are acid in composition, and are allied to those found in the Lower Silurian strata of North Wales. They vary from *quartz porphyries* or *quartz felsites*, which contain porphyritic crystals of quartz, to those which contain quartz only in a microscopic state; *orthoclase-felsites* without individualized quartz (2700) but with porphyritic

crystals of orthoclase (a monoclinic unisilicate of alumina and potash) (1994, 1996) also occur, and Dr. Hatch has determined the existence of felsites rich in soda felspars (oligoclase), and hence called *soda-felsites* or *keratophyres.* As an example of the latter, attention may be directed to (2002), but it is almost impossible to distinguish between the potash- and soda-felsites without a detailed chemical examination. Some of the lavas are more basic than the felsites, and they will be referred to later on as *andesites.* The felsites frequently show a streaky flow structure (2701) characteristic of lava flows, and some have associated with them beds of ashes (2009) and volcanic tuff made up of volcanic lapilli (2017), broken fragments of felsite (2018, 2708, 2024), and broken felspar crystals (2023); this evidence shows that the rocks are the product of ordinary volcanoes, and that they are of Lower Silurian age, and hence older than the granite. Some of the ashes are more basic in composition (2010, 2012, 2709) and suggest that certain of the diabases and epidiorites may have been lava flows. The ashes appear to be more frequent in Wexford, and some occur in Kildare.

Dr. Hatch has examined the coarser grained "greenstones" of Wicklow, and divided them according to their chief constituent minerals. They are mostly *diorites,* rocks whose essential minerals are plagioclase felspar (usually oligoclase) and hornblende. These diorites, while sometimes normal, usually contain some additional mineral such as quartz, often with mica (2028, 2043) or augite (a monoclinic bisilicate of lime, magnesia, and iron), and thus the group is transitional between the basic dolerites and diabases, to be presently described, and the keratophyres, soda granites, and granites of the main chain.

A remarkable group of rocks occurs at Carrigmore, near Rathdrum, including some typical *quartz-mica-diorites,* in which augite occasionally occurs as a constituent, with hornblende and biotite. But one curious rock from this area (2045, 6) contains the following minerals :—apatite, magnetite (cubic oxide of iron), plagioclase felspar, augite, diallage (a platy modification of augite), a rhombic pyroxene (either hypersthene or enstatite), biotite, olivine (orthorhombic unisilicate of magnesia with iron), and probably orthoclase. The specimens from Deputy's Pass and Bologe Lower, belong to the same category, and the free development of bronzy mica is well seen in hand specimens. Occasionally there is less mica and the rocks pass into normal *quartz-diorites* (2047, 8), in some of which augite begins to come in, and this increases in quantity until the rocks gradually pass into *augite-diorites* or *proterobases* (2725,6, 2049), with little or no hornblende, and usually a certain amount of quartz. On the other hand there may be no quartz and little or no orthoclase, when the rocks pass into normal *diorites* (2026, 2711, 2032, 2040). The rock from New Ross (1757), and that from Tincurry (2716), both containing augite with brown hornblende and some biotite, would be best spoken of as *proterobases.*

Placed below the diorites are a few *andesites*, rocks of the same chemical composition as diorites, and often with the same minerals, but set porphyritically in a fine-grained microlithic or crypto-crystalline matrix. These are lavas containing plagioclase with hornblende and augite or a rhombic pyroxene which is usually hypersthene (an orthorhombic bisilicate of magnesia) (1753, 4). A dyke of *hypersthene-porphyrite* intrusive into the Cambrian rocks at Cahore Point is also placed here (2710).

The coarse-grained varieties of *dolerite*, rocks characterized by a plagioclase felspar (labradorite, a lime-soda felspar) with augite and iron ores, are not common, but there are a few rocks which may be described as *gabbros*, although the diallage or coarse augite has been replaced by hornblende and other minerals. The rock from Thomastown (1758) may be termed a *hornblende-gabbro*. Normal *ophitic dolerites* in which the felspar has crystallized first and is enclosed in great plates of augite, are found at Mr. Parnell's quarry at Arklow (2064), where they were quarried for paving-setts, at Knockatober (1756), and near Croghan Kinshela (2056). Most of the dolerites, however, have been transformed into *diabases* by the alteration of the augitic constituent into chlorite and calcite, or into *epidiorites* with the formation of hornblende in place of augite, a change brought about under the influence of pressure which has often induced a schistose structure upon the rock. As examples of *diabases* may be quoted numbers 1987 and 2063, of *epidiorites* 2068, 9, and 2718, and as *schistose epidiorites* verging on *hornblende-schists* 2072, 4, and 5. The rock from Roundwood (3445 and 2060) is a spherulitic diabase or *variolite* which shows rounded bodies called spherulites or varioles, purple or green in colour, embedded on a fine-grained, dark matrix; the rock has doubtless once been a basic glassy rock like the modern tachylites, but has been altered in the course of time with the development of a minute crystalline structure, the crystals aggregating round centres to form the varioles.

The ultrabasic rocks are of limited distribution in Leinster, and have hitherto been only described from two spots. There is a dyke of *hornblende-picrite* (2728) penetrating the Cambrian slates and grits of Greystones, in which olivine (an orthorhombic unisilicate of magnesia with iron) has clearly been once present, but it is now replaced by a pseudomorph of amphibole (probably tremolite), so that the rock is now a pure *amphibolite*. It consists entirely of amphibole in the form of massive hornblende, with fibrous tremolite replacing the olivine, and intruding upon the surrounding constituents. In this form it compares with that from Glendalough (1752), described by Professor Sollas. The latter is very coarsely crystalline in places (3452), and frequently becomes micaceous (3453), while at its edges a considerable amount of felspar has been developed (3454). The chief varieties are to be seen in case A.

The rest of the igneous rocks of Leinster are placed in case B, and are described here in the order in which they are arranged in the case, taking the left-hand compartment first, and beginning at the top.

Case B.—Lambay and Portraine.

(Map B, Sec. 51). The well known dark green rock, with beautiful light green porphyritic crystals of felspar, known as the Lambay porphyry, is found on that Island. It is intrusive into the Lower Silurian shales and slates. Microscopical examination shows that the rock is an altered *andesite* or *porphyrite* (diabase-porphyrite of von Lasaulx), with a base of fine felspar needles and augite largely altered into epidote, embedding crystals of a much altered plagioclase felspar near labradorite in composition (2090). Microscopic sphene, leucoxene, pyrite, and calcite (hexagonal carbonate of lime) are likewise present; occasionally the rock becomes much more compact in texture and does not show any porphyritic crystals (2739), and it is sometimes amygdaloidal. (1894).

An equally beautiful rock is obtained from the Hill of Allen (2085), and from Grange Common Hill (2084), both in Kildare, while dykes of the same general character seam the Cambrian slates of Howth (2086, 2737). The same rock also comes to the surface at Portraine, and a specimen (2087) is shown in Case B. Associated with these rocks in Kildare and Portraine are beds of ash containing fragments of porphyrite, none of which, however, have quite the same characters as the intrusive rock (2089); similar ashes occur in Lambay (2094, 5), and at Skerries.

Case B.—Bellewstown and Herbertstown.

The Bellewstown area exhibits a series of lava flows contemporaneous with the Lower Silurian beds in which they occur, and of rather remarkable types. These comprise platy felspathic rocks, some of which (2100) ring under the hammer, and contain felspar and mica, but usually no quartz; others are *andesites* (2107), and others possibly *felsites*; and with these are bedded felsitic and andesitic *ashes* (2101, 4). There are a few dykes of intrusive rock, some being acid in composition, and with the general character of *microgranites*, like those of Ardcath (2099), and Heathtown (2740). But the chief intrusive rocks appear to be a set of *diabases*, which are extremely common in the little igneous area of Herbertstown, to the south, and thence stretch away to the coast at Gormanstown and Balbriggan.

Case B.—Slane.

(Map B.)—It is probably the same set of rocks which comes to the surface and is interbedded with Silurian rocks to the North-west, near to Slane, and between that town and Oriel Demesne in Louth. The lava flows are chiefly *andesites* (2113), all of which are augitic but some probably have contained hypersthene (1761, 1291), a few are probably *basalts* which may have borne olivine (1303), and some seem related to *felsites* (2110, 1296).

The *ashes* contain fragments of felsite and porphyrite, often of considerable size (1283, 2115). The intrusive rocks are chiefly *diabases* (2111), but at least three masses of a remarkable and rare rock occur here. One is at Bryanstown (1759, 1282) another is either part of the Craig Baron mass or the little area to the north of it (1760), and the third is near Craig's Cross (1305). These rocks are *augite-syenites*, made up of large crystals of green pyroxene embedded in plates of crystalline orthoclase mixed with which is some plagioclase felspar, a constituent more abundant in some localities than in others. Apatite prisms are extremely abundant in all these rocks. Another type of intrusive rock belongs to the *lamprophyres* (*i.e.* dyke rocks consisting of felspar with mica, which may be more or less replaced by augite or hornblende); it is found at one mile N.W. of Devlin's Bridge (1294), at Starinagh (2742), and at Oriel Demesne (2119.) The rocks are *minettes* or *kersantites*, probably the former, with brown mica and sometimes a little augite.

Along the strike of the rocks of Oriel Demesne, where they would meet the sea at Clogher Head, the Silurian rocks are penetrated by a number of dykes, some of which are irregular and branching, and by sills intruded parallel to the bedding. The best preserved of these is a *lamprophyre* (3523) with large crystals of biotite undergoing change into chlorite; others contain muscovite; some of them possess porphyritic felspar in addition; not a few show relics of augite, and when the mica is more decomposed and less recognisable seem to pass over into *diabases* (3543.) One dyke is a *felsite* (3547) with porphyritic orthoclase and plagioclase and some mica; it is a pale buff rock, the lamprophyres having a pale shade of sea green. There is no evidence of contemporaneous volcanic activity in this region, and the igneous rocks are later than the Lower Silurian, and possibly later than the Upper Silurian Period in date.

The Carboniferous rocks of Duleek (2108) and Gillinstown (2109) are penetrated by dykes of fine-grained black *basalt* (a finely crystalline rock consists of labradorite, augite and magnetite, a cubic, magnetic, iron oxide), which are usually amygdaloidal and contain olivine. They are quite fresh and are clearly later in date than the Carboniferous Period; they may even be of Tertiary age.

CASE B.—KINGSCOURT AREA.

(Map B.)—In connexion with the rocks last mentioned, it is convenient to turn to the beautiful and fresh basic rocks of Kingscourt. These are *dolerites* with porphyritic crystals of plagioclase felspar which are glassy, zoned, and twinned; these felspars are set in a fine ground of felspar prisms, which again are embedded in continuous crystalline masses of augite, so as to show that the felspar crystallized first and was followed by the augite: such a structure is termed ophitic. Plenty of olivine is present, but it is not usually fresh, being altered into serpentine (a hydrous silicate of

magnesia) and iddingsite. These *olivine-dolerites* are intrusive into the Coal Measures (1314) and the Triassic rocks (1328, 1332) of Kingscourt and Ardagh (1319).

Case B.—Louth and Carlingford.

(Map B.)—Passing north to the great igneous tract of Carlingford we meet with a complex of rocks, which may be briefly considered under a few chief heads. The oldest rock appears to be the *eucrite* or *anorthite-gabbro* (2744, 5, 2124), which is well seen at Slieve Foye and Barnaveve. Dr. S. Haughton has analysed the rock and the felspars isolated from it, and further researches have been carried out by Professor Sollas. It contains about 47 per cent. of silica, and has for its chief constituent a lime-felspar called anorthite (triclinic unisilicate of lime and alumina), or one beween bytownite and anorthite in composition; this is mixed with iron ores, hypersthene, and pyroxene which has minute lustrous plates deposited along several of its planes so as to give it the bronzy lustre and structure of diallage. This gabbro is penetrated by dykes and veins of *granophyre*, a rock allied to granitite in composition, and composed of quartz, orthoclase, albite, green and black mica with magnetite, sphene, and rare zircons; the quartz and felspar are intergrown together in intimate crystallographic relationship, so as to form the aggregate known as micropegmatite. The penetration of the gabbro by the granophyre is of the most intimate character, the veins being at times mere threads, and Professor Sollas is of opinion that the micropegmatite which occasionally forms a matrix to the gabbro is due to injection of the granophyre on a minute scale. Further he regards the patches of gabbro immersed in the granophyre as connected by insensible gradations with the crystals of augite sometimes found in it, and he considers both to be the survival of included bits of gabbro which have escaped melting down by the heat of the intrusive rock. These rocks are certainly later than Carboniferous time, and may even be of Tertiary age; they compare closely in structure and composition with similar rocks in the Mourne Mountains, in Skye, and in Mull. Later dykes of black basalt traverse both granophyre and gabbro, and occasionally extend to a considerable distance into the bordering rocks (2122).

Case B.—Phillipstown.

An interesting area of volcanic rocks occurs at Phillipstown in Queen's County. These are bedded with the Carboniferous Limestone, and are the only instance of volcanic action of that date known in Ireland except that of Limerick, to be described later. The *breccias* and ashes, made up of basalt, pumiceous rock, and palagonite, but containing fragments of limestone often of considerable size (1604, 1610), embedded in fine ash (2081), or in crystalline calcite (1613), show that the outburst was actually of Carboniferous age. The lavas are vesicular and amygdaloidal *diabases* (1606, 1614), but at times are made up of *limburgites* like those of Limerick, and of compact, intensely dark *basalt*

(2733, 5), which has a very remarkable character. In a base of felspar and augite rich in brown mica are porphyritic felspars which themselves enclose idiomorphic crystals of augite. There are two old specimens in the collection of which the exact history has been lost, but which have certainly come from a small patch S. E. of Gorteen. One (2732) contains relics of garnets surrounded by rings of kelyphite embedded in a mosaic of felspar, with a mineral which may possibly be idocrase; the other (2734) contains the relics of garnets preserved as kelyphite, set in a matrix of quartz grains, much strained, and containing a profusion of crystals of greenish, yellow, or red sillimanite. This appears to be a metamorphic rock, and may be a fragment of some sediment enclosed in the igneous rocks.

Case B.—The Carnsore Area.

This region is at present undergoing re-examination, so that it is not possible to display an exhaustive collection of its rocks. It is occupied largely by a plutonic complex of *granitites* (granites without muscovite) consisting of quartz, microcline and orthoclase often in large pink porphyritic crystals, and biotite with iron-ores, apatite, and zircon (2079, 80). The normal granitite passes into *gneisses* which are well banded, much crushed and crumpled (1806), and penetrated by a great series of basic and ultrabasic dykes in which hornblende is an important constituent. Many types of schistose rocks occur in the neighbourhood of the granite.

3. THE FOLIATED CRYSTALLINE ROCKS OF LEINSTER.

Cases VII. and VIII.—The Flanks of the Leinster Granite.

(Maps A & B; Sec. 51). The metamorphism produced in the surrounding Lower Silurian strata by the intrusion of the enormous and highly heated mass of the Leinster granite has not received any detailed investigation since the work of von Lasaulx. Originally they were chiefly clay rocks with coarse gritty bands, penetrated by the intrusive rocks already specified. The grit layers are less easily altered than those of slate (2669, 1266), and their original structure is observable even after the interbedded slates have been converted into mica-schists. The slates first begin to show a micaceous glaze and a slightly knotted structure on the cleavage surfaces even at a very considerable distance from the margin of the granite (1270, 1). The mica crystals then steadily increase in size, and are associated with staurolite (an orthorhombic subsilicate of alumina and iron), both minerals containing graphite (hexagonal carbon); further still the mica is interleaved with bands of granular quartz in grains interlocked with one another,

and whose shape has probably no connexion with any original fragmental structure. These *mica-schists* are generally much crumpled (1250). Locally they become spotted, and, on tracing them towards the granite, the spots pass into crystals of andalusite (orthorhombic subsilicate of alumina), which are often of considerable size. This is especially the case where the rock is seamed with granite dykes, as at Killiney (3478, 1248), (*v.* D. 21). Specimens showing the actual contact are exhibited in case A and also here (1257). The patches of schist actually enclosed in the granite have suffered a much higher metamorphism. Amongst the minerals developed in such a case are staurolite, garnet, idocrase (teliagonal unisilicate of lime and alumina) (1262, 5), zinnwaldite (an iron-lithia mica) (2670), tourmaline (1259), and actinolite (a magnesia-lime-iron amphibole), 1252).

Where the same rock has been intruded upon by basic and acid rocks, as in the neighbourhood of the amphibolite intrusion at Glendalough, an intensely crystalline *mica-schist* has been produced (3444). While the bulk of the metamorphism is undoubtedly attributable to the intrusion of the igneous rock, some must be due to mechanical deformation, which has left its mark in many cases on the margin of the granite itself, by inducing a foliated structure on it. This is well seen about Graigue-na-managh in Carlow, where the granite passes into a well-foliated gneiss (Case A, 1260).

At Thomastown, where the granite is intruded into the surrounding rocks in a number of small masses, there occur a few singularly coarse-grained hornblendic rocks, either altered by the intrusion of the granite or else, if they are the later, cooled slowly, because the granite was still hot during their intrusion.

A great many of the igneous rocks flanking the Leinster granite are altered from their original character, in all probability by dynamic metamorphism. Thus felsites are crushed until they resemble cleaved felspathic ashes (1218, and some placed in case A); ashes are strongly cleaved and secondary minerals developed, while dolerites are altered to *epidiorites*, and even to *hornblende-schists* and *schalsteins*.

2.—CONNAUGHT.

1. GENERAL ACCOUNT OF THE ROCKS.

Connaught is divided geologically into two very dissimilar parts by a line running from Sligo to Galway—the western tract of mountains and the eastern plain. The former is again severed into three regions by belts of Silurian strata; the region extending from Benwee Head to Achill and Lough Conn, which sends out a long north-east tongue to the Ox Mountains and Slieve Gamph, is divided from that of Croagh Patrick and Westport by the

Carboniferous-covered Silurian trough of Clew Bay and Clare Island, and this in turn is separated from the Connemara Mountains by the trough of Lough Mask, Killary Harbour, and Mweelrea. All this ground, except where otherwise stated, is occupied by gneisses and schists, quartzites and marbles, of great antiquity, pierced and seamed by intrusive rocks of several types, from the acid granites of Blacksod Bay and Galway to the serpentines and picrites of the Ox Mountains and Roundstone. The highest summits and most picturesque peaks are built of quartzites and quartz-schists, diversified by steep cut valleys and abrupt escarpments where the bedded and less metamorphosed Silurian rocks come to the surface. The coast scenery corresponds with that inland, and the harder masses of resisting rock rear themselves against the waves in lofty cliffs, like those of Achill, which tower nearly two thousand feet above the sea.

East of this line all is changed, and the broad Carboniferous Limestone plain stretches away eastwards to join that of Leinster, broken only where older rocks push up to the surface, giving rise to more rugged country at Ballaghaderin, Slieve Baun, and Slieve Aughty; where plateaux of higher Carboniferous rocks stand above the surrounding country in the form of terraced scarps and outliers, like those of Ben Bulben and Lough Allen; or where the limestone of the southern margin itself takes on similar characters, and forms the terraced steps characteristic of the "Burren area."

The dividing line between the mountains and the plain is marked by the western chain of great lakes, Loughs Conn, Mask, and Corrib, continued by a belt of broad river valleys and sea gulfs, rather a significant feature when the general relations of scenery to geological structure in Connaught are carefully studied.

In descending order the principal rock groups in Connaught may be thus specified:—

Systems.	Series.	Igneous Rocks.
5. Pleistocene, . . .	—	—
4. Carboniferous, . .	Coal Measures, ...	Intrusive Rocks.
	Millstone Grit, ...	
	Yoredale Series, ...	
	Carboniferous Limestone, . .	
	Lower Carboniferous Sandstone,	
3. Old Red Sandstone, .	—	—
2. Upper Silurian, . .	—	Intrusive and Interbedded Rocks.
1. Lower Silurian, . .	—	Intrusive and Interbedded Rocks.
Foliated Crystalline Rocks.	—	Intrusive and Interbedded Rocks.

Cases XV.-XVIII.—The Foliated Crystalline Rocks.

Although it is by no means proved that the rocks of the mountains are the oldest in the Province, yet as some of them present structures and mineral characters not met with amongst unaltered sediments, and as no definite relationship has as yet been conclusively established between these two groups of rocks, it will be convenient to treat them first, premising that by so doing there is no intention of prejudicing the discussion of their age For convenience of description the district will be split up into four areas running from north to south. 1, *North Mayo*, the Belmullet and Blacksod region with Achill Island and Curraun Achill as far as Nephin; 2, *Southern Mayo*, the district of Westport and Croagh Patrick; 3, *Northern Galway*, including the Omey, Clifden, and Leam areas, with the islands on Lough Corrib; 4, *South Galway*, the area from Roundstone to Galway Town.

Case XV.—The Ox Mountains, Belmullet and Achill. (Map C.)—The chief Plutonic rocks of the Ox Mountains are coarse porphyritic *granites* (*v.* page 52) at times graduating into *gneisses*, which contain all the constituents of granite but are foliated. At the western edge these rocks pass under a series of *mica-schists* (2887), *quartz-schists* (1123), and *sheared grits* (the rock called "pennystone" in this area) (874) like those occurring in Donegal. This series, which in the nature and association of its component rocks presents every reason for supposing it to be of sedimentary origin, sweeps across Mayo from Nephin to Belmullet, its constituent members being several times repeated by folds, the quartzites (2999) and quartz-schists forming mountainous country, the mica schists and lead-coloured phyllites forming rolling uplands. The *limestones* are gritty, full of fragmental quartz, and foliated with layers of emerald-green mica (3023). These rocks come into contact with *gneisses* (1128, 1132, 2952) and *granites* about Belmullet, their contact with the latter being clearly due to intrusion of the granite, which has produced, along the junction planes, a *knotted schist* (1146, 1134 and 5) with "eyes" of felspar surrounded by folia of mica. The junction with the gneisses is usually a thrust plane (3018), and the gneisses are massive (1126), hornblendic or actinolitic (1130), micaceous (1135), granulitic, much contorted (1128), and penetrated by dykes of amphibolite (1145, 1129), epidiorite (1138) and recent basalt. A fine grained, slabby, *quartz-schist*, very like that known as "*moyne-schist*" in the Scottish Highlands, is found to the east of Erris Head (1131).

Following the sedimentary series down to Achill Island the chief features are the abundance of *quartzites* (1150) and *quartz-schists* (1151) passing into massive quartzose *conglomerates* (1148) which have been much crushed by earth-movement so that the pebbles have been sometimes drawn out to threads (1149).

Case XV.—Croagh Patrick and S. Mayo (Map C. and D.; Sec. 30). A belt of *mica-schists*, coarse, foliated, pebbly, *grits*, and *graphitic schists*, flanks the Croagh Patrick range to the north and passes to Westport to join the similar rocks of the Ox Mountain area. *Quartzites* occur on Croagh Patrick, and to the north there is a great mass of *serpentine* (1153, 4, 5) probably produced by the metamorphism of an igneous rock. *Knotted schists* with all the characters produced by contact-metamorphism occur in the neighbourhood of the Corvockbrack granite.

Cases XV., XVI., and XVII.—Northern Galway (Map D.) This area includes the interesting ground between Omey and Clifden, that about Leam, and the Islands on Lough Corrib. The rocks chiefly represented are *muscovite*-(1157), *chiastolite*-(1159), and *talc-schists* (2513), *limestones* (1169) and *dolomites* (1170), including the beautiful marbles of Cregg quarries (655, 6). These would be more valuable if only they could be raised in larger blocks. Copper ores have been found in this neighbourhood. Associated with the limestones are *ophicalcites* and *serpentines* (1161, 4, 5, 6, 7, 1182, 3, &c.) from Streamstown, Recess, and elsewhere, which form the beautiful Galway marbles and "Eozoonal rock" (1162), so called from its resemblance to the Canadian rock which was once supposed to contain the earliest known fossils. These rocks consist of fine or coarse puckered bands of a light green serpentine alternating with layers of crystalline calcite. Some of the darker and more massive serpentines which have the characters found in those derived from igneous rocks, are translucent and very beautiful (1181). These serpentines, ophicalcites, and marbles are most useful for internal work, as is admirably shown in the Museum of Science and Art, the National Library, and many public buildings in Dublin. About Leam the rocks are chiefly *knotted schists*, some of which are probably produced by contact alteration (2923), others are of the *foliated grit* type (687). Associated with these are lead-coloured *mica-schists* (2910), *phyllites* often much puckered (2924), and *hornblende-schists*, probably in most cases produced by the metamorphism of basic dykes (1178, 2563). There are *garnet rocks* (887), *quartzites* (702), with foliated and crystalline *limestones* (657, 8). *Gneisses* also occur (2541), but some of these are certainly foliated granites. Similar *gneisses* (1184, 5) and *schists* (1187, 97) occur on Lough Corrib and its islands, associated with the *serpentines* (1189, 90, 92) to be subsequently described (*v.* page 55).

Case XVIII.—Southern Galway. This area extends eastwards from Roundstone to Galway. About Roundstone and Slyne Head in south-west Galway *mica-gneisses* (1200) occur associated with *hornblendic gneiss* (1173), *epidote rock*, a rock mainly made up of epidote (an unisilicate of lime, iron, and alumina) (1175), and "*moyne-schist*" (1158), all being penetrated by the igneous rocks to be mentioned later on (*v.* page 53). At Town Park on S.E. Galway, the plutonic complex includes many foliated rocks, but

very few which can be safely referred to a sedimentary origin. The massive foliated rocks will be described in connexion with their igneous accompaniments (*v.* page 53).

Cases XI. and XII.—The Silurian System.

The rocks of this System come to the surface in three very important areas ; at *Ballaghaderin*, the environs of *Clew Bay*, and between *Mweelrea* and *Lough Mask*, besides other and less important regions like that of Slieve Baun and Slieve Aughty about Loughrea. The rocks do not present any great differences from those already described in Leinster, but the local peculiarities will be noted below. Lower and Upper Silurian rocks appear to occur in the same areas, but the lowest rocks of the system are not known there, a significant fact when taken in connexion with the absence of all Cambrian rocks. A remarkable feature is the presence of contemporaneous volcanic rocks in the Upper Silurian System, a thing not known in Britain, and only paralleled by the igneous rocks of Clogher Head in Kerry. Another important point is that some of the Silurian rocks are so intimately associated with crystalline schists that it is not easy to draw a boundary line between them, and this has led to the belief, which may possibly be correct, that the sediments have passed into foliated crystalline rocks under the influence of metamorphism.

The rocks are of little economic importance, but hæmatite has been worked at Lough Gowna and Drumsna, while anthracite in nearly vertical beds occurs at Kilnaleck, and lead and other veinstones exist in the Silurian and Carboniferous rocks near Lough Mask. Some of the most striking scenery in Galway and Mayo, as at Killary Harbour, Mweelrea, and Delphi, is situated in these rocks. The fossils will be noted under the localities in which they have been found (*v.* page 112).

In the district of **Uggool and Ballaghaderin** two divisions of the Upper Silurian rocks are represented on the published Survey maps; the lower, containing fossils attributed to Upper Llandovery time, consists of red and purple sandy *shales* (926) with *sandstones* and *grits* ; the upper, or Wenlock rocks, are deep purple *flags* with a few *shale* beds, and a band of concretionary *limestone*. Associated with the upper division is a series of volcanic rocks, including columnar and other felsites and their associated breccias and ashes, with intrusive masses of augitic granophyre and diabase dykes (*v.* page 51).

About **Mohill, Drumod, and Ardglass** the Silurian strata consist of dark greywacke *grit* with bands of *slate* (1440) like that found in the Slieve Baun area to the south-west ; the few fossils found near Slieve Baun indicate that Llandeilo, or Bala, or even possibly both Series are present.

Patches of Silurian rocks, *slates* (859, 860), and *grits* (1119) occur at Louisburg, west of Croagh Patrick, and on Clare Island (695), where an Upper and a Lower division have been separated

and mapped. Fossils are found in the calcareous *shales* of this area (928), and some of the slates and grits have the aspect of such alteration as is produced by the intrusion of igneous rocks.

The **Mweelrea** and **Slieve Partry** area (Map D; Sec. 30). Mr. Kinahan has divided the Silurian rocks into the following subdivisions, in descending order, and he suggests the annexed correlation with English equivalents:—

4.	*Salrock Beds*,	= Ludlow Series.
3.	*Mweelrea Beds*,	= Wenlock Series.
2.	*Owenduff or Gowlaun Series*,	= Llandovery Series.
1.	*Doolough Beds*,	= Lower Silurian System.

The Doolough Beds consist of olive green *shales* and *slates* (1120) alternating with thin greenish *grits* (696), and *sandstones*, sometimes pebbly (646). Many fossils have been found in these beds, and are referred to on page 112. The Owenduff or Gowlaun Series consists of *conglomerates* (1003), *grits* (647, 8, 9), *slates*, *shales* (929), and *quartzite* (869), with a bed of *limestone*, and at certain horizons beds of interstratified (?) felsitic lava. The Mweelrea Beds are coarse green and purple *grits* with interbedded massive *conglomerates* and olive *green* slate bands, associated with intrusive felsites near Killary Harbour, and lavas of felsitic and andesitic composition about Lough Nafooey. The Salrock Series is made up of green *slates* (923, 4) and thin-bedded *grits*, occasionally fossiliferous, covered by red *slates*, thick quartzose *grits*, and *limestones* (875). A large series of fossils has been obtained from the Upper Silurian strata, including characteristic Corals, Trilobites, Brachiopods, Gastropods, and Cephalopods. As the Geological Survey is at work upon this district it is possible that the classification and correlation given above will need modification; at present it is safe to state that the quartzite of Lough Nahaltora, which is identical with that of Croagh Patrick, both containing a thick boulder deposit, appears to underlie the Doolough Beds, and is in turn apparently underlain by indurated fossiliferous strata which pass eastward into phyllites and mica-schists, and appear to rest on green and banded grits. Some of these rocks are metamorphosed by the intrusion of the Corvockbrack granite. The Silurian rocks as a whole give rise to a picturesque country cut up by deep valleys into mountains which, at Mweelrea and near Delphi, rise to a considerable height, and give birth to many streams in their flat bottomed, steep-sided corries, which are called lugs in the locality. Some of the slates are worked for roofing purposes.

In the **Loughrea area** the hard, black, coaly *shales* (1638) which contain Graptolites, and are interbedded with soft grey shales (1636), are probably of Llandeilo age, and the overlying *conglomerates* and *sandstones* seem to belong to the Bala or Caradoc Series.

Case XII.—The Old Red Sandstone.

This division covers only small areas in Connaught; it just fringes the main Silurian tracts, and occasionally crops out alone amongst the surrounding Carboniferous strata. It probably all belongs to the higher division of the System, with which it corresponds in lithological characters, as will be seen from the detailed descriptions. It yields no products of economic value, as a rule forms a physical as well as a geological fringe to the Silurian country, and has yielded no fossils except occasional plant remains which are referred to on page 113.

The *conglomerates* and reddish brown *sandstones*, 300 feet thick, which pass conformably upwards into the Carboniferous rocks and rest unconformably on the older rocks of **Curraun Achill** (Map C), together with the yellowish *sandstones* which appear as conformable inliers amongst the Carboniferous rocks at **Slieve Dart** (where there is a mass of yellowish felstone), **Castlereagh** and other localities, are now considered to be the local base of the Carboniferous rocks.

The long strip which extends from **Lough Allen to Ballaghaderin** contains some remarkable rocks, which are partly volcanic in origin. About Boyle and the Curlew Hills they are broken up by extremely sharp rectangular joints, and consist of very compact *grits* (2470, 3) and *breccias* (2471, 2) almost exclusively composed of small and large fragments of felsite, and probably made out of volcanic material ejected into water and then compacted into rock; pebbles of slate, schist, jasper, and vein-quartz are, however, to be found sparingly in this rock.

Old Red Sandstone rocks cover a considerable area north of **Westport** and west of **Castlebar** (Map C and D). They consist almost exclusively of *conglomerates*, the "Croaghmoyle conglomerate," made up of fragments of granite, sandstone, and quartzite, with rare seams of sandstone. They are estimated to be from 700 to 1,000 feet in thickness, and they give rise to a rugged country with lofty conglomerate cliffs.

The rocks mapped as Old Red Sandstone about **Slieve Baun** consist of siliceous *grits* and *sandstones* (723), passing into subangular *conglomerate* (1441), which contains large well-rounded pebbles of Silurian grit and smaller subangular pieces of the same material. Lumpy masses of siliceous rock (a kind of jasper, 651) occur here at the base of the Series and fill up hollows of denudation in the surface of the Silurian rocks.

The **Loughrea and Slieve Aughty area** has banded brown and chocolate coloured *sandstone* (1632), interbedded with purple micaceous sandy *shale* (1635), quartzose *conglomerate* with fragmental felspar and epidote (1640), and occasional seams of "*cornstone*," an impure earthy and ironstained limestone.

Case XIII.—The Carboniferous System.

The divisions of this System that occur in Leinster are also to be recognised in Connaught. The fragmental basement beds, however, are more widespread and better developed, while the limestones are on the whole purer. In some parts, indeed, the whole of the Carboniferous Limestone Series must be treated as one, for such lithological divisions as do occur cannot be traced far, and until recognisable zones of fossils are established it is hopeless to attempt to establish a tripartite classification over the entire area; for this reason no divisions have been hitherto established in the middle of the Province, or else the Limestone has been all relegated to the lowest Stage. The higher Carboniferous rocks are only to be found at the North-east, where the presence of the huge outliers of Lough Allen indicates the former great extension of those beds to the west, and the enormous amount of material which must have been removed by denudation in the interval between the Carboniferous Period and the present, an interval during which this part of Ireland has probably been above water and exposed to the action of rain and streams.

The thickness of the rocks of this System at its maximum development appears to be between 5,000 and 6,000 feet, but as the different beds attain their maxima at different places this thickness would never be met with at one spot.

As in Leinster the limestone rocks yield black marbles near Galway and splendid building material, durable and capable of delicate workmanship, in Galway, Mayo, the Arran Islands and elsewhere. The sandstones of the Yoredale and Millstone Grit Series yield freestones, sometimes glazed along the joints with quartz so as to be extremely durable; flagstones and the thin, smooth, laminated, flag used for roofing, and known as "Dunmore slate," are also obtained from these rocks.

Lower Carboniferous Sandstone (Sec. 30).—Owing to its low dip and its considerable thickness this sub-division covers a large area in Mayo to the west of Killala Bay, and it crops out from under the edge of the Carboniferous Limestone whenever that Series abuts on more ancient rocks in the northern part of the Province. It becomes thinner when traced southward, doubtless owing to the wide extent of the deep Carboniferous sea over the rocks of Connemara, but it begins to assume more importance on the borders of the Slieve Aughty range, when it takes on the characters of the Lower Limestone Shale of south-west Ireland.

In the Killala Region the total thickness of strata is about 1,000 feet and the rocks roll in gentle curves, here and there broken by faults and penetrated by one or two large intrusive dykes of dolerite (*v.* p. 51); they are red, brown, yellow, and earthy *sandstones*, dark brown *shales*, calcareous *sandstones*(701), and sometimes thin bands or concretionary nodules of *limestone*. The band bordering the east of Slieve Gamph appears to be only 150 feet thick, and is based on a quartzose *conglomerate* followed by purple

sandstone and calcareous *grits* (699, 700) containing a few traces of fossils. The rocks maintain pretty much the same character when they reappear to the north-east about Ballaghaderin and Boyle, except that a basal *breccia* derived from the denudation of the Old Red volcanic rocks occurs here (2474); the few inliers, mostly of *conglomerates*, *grits* (1434, 6), calcareous *sandstones* (1433, 8), and micaceous flagstones which appear from beneath the great Limestone Plain are now regarded as the Carboniferous basement, and not as Old Red Sandstone. Bounding the north side of Slieve Aughty come about 150 feet of *shales* with shells (1631), shaly *limestones* (1646), and occasionally *grits*, *flags*, and *sandstones*.

The Lower Carboniferous Limestone.—South of Killala Bay the Limestone Series begins with a bed of *oolite* about 80 feet thick (861), in which elongated crystals of quartz occur; this is followed by a fine crystalline *limestone* (705, 6) banded with *shales* and altogether not less than 600 feet in thickness. In the neighbourhood of Skreen the *limestone* has been much crushed and specimens show "slickensided" surfaces (856, 7). In the great Limestone tract east of Sligo Bay the lowest division is feebly developed as a band of *magnesian limestone* about 100 feet in thickness, showing occasional pebbly bands at the base when it comes into contact with the underlying crystalline rocks; but to the south-east it is more important and yields good building and even ornamental stone. About Boyle and Carrick-on-Shannon, there are light steel-grey to dark-grey *limestones* with occasional beds of *shale* and bands or nodules of *chert*.

Over the western part of the great central plain the *limestone* is grey, pure, and fossiliferous, massive or flaggy, with beds of *grit* at the base, but not divisible into separate series, although it has been possible to roughly relegate certain portions of the Series to a lower stage, and others near Roscommon to the middle division. The Lower and Upper Limestones of the Slieve Aughty range are very pure and free from sedimentary ingredients, though they contain some beds of *chert*. They are crinoidal (1622) often dark and shelly, (1644) and sometimes seamed by dyke-like plates or masses which have the composition of *dolomite*. The alteration of these portions is almost certainly due to magnesian water percolating into the mass of the rock from the walls of the joints by which the rock is traversed. The Lower Limestone is about 2,000 feet thick, and although it is thinner towards the east, bands of shale and sandstone make their appearance in that direction, especially in the central part of the Stage.

The Middle Carboniferous Limestone.—For reasons already stated this division requires separate description only at a few places. East of Sligo Bay there is a lower *sandstone* division 500-800 feet thick towards the north, followed by calp *shales*, and *limestone*, frequently fossiliferous, with masses of corals, and *chert* bands amounting to 700–1,000 feet in thickness; landslips are of fre-

quent occurrence in these rocks. Argentiferous galean and blende have been worked at Abbeytown in veins in the Middle Limestone. About Castlebar (Map C) the Lower Limestone seems to be absent and the lowest rock seen is a division which corresponds to the Calp, and near Loughrea the Middle Limestone is dark in colour and crinoidal (1628); it contains *chert* bands (1627). A good idea of the bedding of the limestone is given by the photographs (P. 81, 92) of Aughros Head in Sligo.

The Upper Carboniferous Limestone.—A fine, grey, crystalline, *limestone* succeeds the Calp to the east of Sligo Bay and forms the great plateau on the summit of Ben Bulben and the other outlying "buttes" or hills about Sligo. It is 700 to 1,000 feet thick and is much traversed by joints. The streams and springs penetrating along these fissures have dissolved out lines of ravines and caves which follow the direction of the dominant joint systems. Near Lough Allen and Lough Arrow the limestone is penetrated by pot holes and swallow holes resulting from the same cause, into which rivers and streams plunge and flow underground as they do in the Ingleborough region in Yorkshire, and many other limestone tracts. Towards the south this division thins down to 300 or 400 feet. A very peculiar structure is noticeable in the limestone at Ballymore in Roscommon, where the strata are traversed by vertical planes like slickensides which, however, do not in any way break the continuity of the limestone beds as they would do if they resulted from faulting in the ordinary sense (653). The Upper Limestone of Loughrea and that of the Aran Islands is so exactly of the Burren type—to be described under the Province of Munster—that it is needless to do more than refer to it here.

The Yoredale Series.—The great outlier of the Lackagh Hills and Lough Allen is based on masses of *sandstone* and *grit* which often give an excellent building stone. They are evenly bedded and about 300 or 400 feet thick, and are succeeded by 500 feet or so of fossiliferous black *shales* with a little worthless *coal* and bands of *ironstone* (930, 932) of which the best known were at one time largely worked at Creevalea and Arigna. The thickest ironstone is a continuous band varying from 6 to 10 inches in thickness, and containing about 40 per cent. of metallic iron.

The Millstone Grit Series.—In the Connaught Coalfield this series consists of massive, white, exceedingly hard, quartzose, *grits*, and *flagstones*, quarried near Lough Doo, with fine *conglomerate* capping the higher hills of Lough Allen, and forming the great scarp of Slieve-an-Ierin. There are two seams of *coal*, the lower called the "Crow Coal" from 2½ to 4 feet thick is valueless because it is full of shale and other impurities, but the upper, 60 feet above it, called the "Middle Coal," though only from 1 foot to 2 feet 6 inches thick, has been much, and profitably, worked in the three districts into which the field is divided by denudation, the N.W. district, that of Arigna, and that of Slieve-an-Ierin. The

Millstone grit appears to be about 150 feet thick, and there are generally seams of impure *fireclay* associated with the Crow Coal. The coals contain from 7 to 20 per cent. of ash.

The Lower Coal Measures.—These contain marine fossils in the Connaught field and are made up of 100 feet of dark brown and black fissile *shales* passing towards the south into *flagstones* and *grits* with one seam of *coal*, the "Top" or "Third Seam," which is 1 foot 8 inches thick in the north-west district, but of little value.

Case XIV.—The Pleistocene System.

The Lower Boulder Clay.—This deposit is much like that already described from Leinster. It occurs in similar drumlins which are parallel to the ice striæ in direction, and are made up of *clay* containing chiefly blocks of local rocks and sometimes blocks of exceptional character, like the gypsum fragments found near L. Allen (707). Occasionally shells and shell fragments are found in it, and it is at times stratified. The earlier direction of movement appears to have been outwards from the great snow shed already described—that is to say, radiating out from a point near Ballinrobe; but later in the period, Scotch ice seems to have overpowered the local ice, and the movement north of the snow shed was roughly from N.E. to S.W. Specimen 1122 is a portion of the rock under the Boulder Clay of Mutton Island in Galway Bay, to illustrate the striation of the rock over which glaciers have moved.

The Middle Sands and Gravels correspond with those occurring in Leinster and are frequently present, and the *Upper Boulder clay* and *local moraines* of the Connemara Mountains call for no further remark. **Eskers** are frequently present; sometimes they are of great size, and erratic blocks occur on them.

Terraces of deposit or denudation are to be found high up on the flanks of some mountain ranges; thus Mr. Kinahan describes mountain terraces between 60 and 200 feet above sea level in the neighbourhood of Killary Harbour, and others between 300 and 1,200 feet high about Lough Graney.

The **Peat Bogs** are either mountain or valley bogs; those of the latter type often occur in the hollows between drumlins and are sometimes more than 30 feet in depth. Varieties of peat have been distilled for gas-making, as at Daranmona in Galway, (677). **Shell marls** are of frequent occurrence under the peat, and *bog iron ore* used at one time to be a valuable commercial product; it is now, however, very rarely excavated. The calcareous springs in limestone districts sometimes form considerable deposits of *tufa*, which is either deposited alone or as a cement for gravels and sand.

2. THE IGNEOUS ROCKS OF CONNAUGHT.

It is only possible to arrange the igneous rocks of Connaught on a geographical basis. The following areas are dealt with separately:—1. *Killala and Castlebar;* 2. *The Curlew Hills,* in Roscommon; 3. *The Ballaghaderin area;* 4. *North-west Mayo;* 5. *The Ox Mountains and Slieve Gamph;* 6. *South Mayo;* 7. *North-west Galway;* 8. *South Galway,* including the areas of Leam, Lough Corrib, Roundstone, and Galway.

CASE C.—KILLALA AND CASTLEBAR.

(Map C.)—On the west side of Killala Bay the Lower Carboniferous Sandstone is penetrated by dykes of coarse-grained *dolerite* or *gabbro* (2481), an ophitic rock, consisting of labradorite and augite, with some biotite, iron ores, and a little hornblende and olivine; the constituent minerals sometimes have a parallel arrangement (1883). The rock may possibly be of Tertiary age. In the neighbourhood of Castlebar somewhat similar but less coarse-grained rocks are to be found; they are intrusive into the Carboniferous rocks or the older masses in close proximity. These are fine or coarse-grained *olivine-dolerites* (2482, 3).

CASE C.—THE CURLEW HILLS.

In the Curlew Hills, about Boyle and Lough Key, volcanic tuffs, probably laid down in water, occur (2472, 3). The constituent fragments are chiefly *porphyrites* and trachytic *felsites,* and the ashes are interbedded with the Old Red Sandstone Series. Some intrusive bosses and dykes of ophitic *olivine-dolerite* of post-Carboniferous or possibly Tertiary type occur at the Rock of Doon (2475) and Moygara Castle (2477).

CASE C.—BALLAGHADERIN.

Associated with the Silurian rocks of Ballaghaderin there is a very interesting series of volcanic rocks, which appear to be for the most part contemporaneous with the Silurian strata amongst which they are found. They consist of *tuffs* and volcanic *ashes* containing vesicular lapilli of andesite, and fragments of felsite and of basic rocks, associated with red or green columnar *quartz-felsites,* some of which are almost certainly lava flows (2885), while others, like the *quartz-porphyries* (2478, 1884), are more likely to be intrusive, and to represent the sources of the felsitic lavas. Dykes of *dolerite* occur occasionally, and one mass of *augite-granophyre,* in which the quartz and felspar are intercrystallized in the form of micropegmatite, occurs near Tawnyinagh (2479). This latter rock bears much resemblance to the intrusive rocks of Charnwood Forest, in Leicestershire, while the felsites and ashes could also be matched in the same area.

CASE C.—N.W. MAYO.

The great foliated series of N.W. Mayo contains here and there undoubted masses of unfoliated plutonic rocks, while it is quite clear that much rock of similar origin is now foliated and so entangled amongst the rest of the "metamorphic" rocks as to be undistinguishable from them. The *granitite* of Blacksod Bay (2487), which has been quarried as an ornamental stone, is an example; its junction with the neighbouring rocks is quite clear, for it passes into a coarsely crystalline pegmatite, with orthoclase crystals one inch long, at its margin (2966). Granite which is more or less foliated occurs at Goolamore Lodge (2489). The foliated series is also intruded upon by numberless dykes of *epidiorite*, presenting all stages of alteration from the original *dolerite* (or diabase) to *hornblende-schist* (2490), ultrabasic *amphibolites* (2890), and *basalts*, which are possibly of Tertiary age, and are quite fresh in their minerals and often amygdaloidal (2491) in texture.

CASE C.—THE OX MOUNTAINS.

(Map C.)—What has been just stated applies with equal force to the Ox Mountain rocks. A coarse porphyritic *granite* is the chief rock, but it is foliated throughout the greater part of its wide extent. *Hornblendic diorites* or *epidiorites* are frequent (2485), with *hornblende schists* derived from them. In the gap S. of Lough Gill there is a very beautiful *serpentine* which is banded and seamed with veins of chrysotile (3262). It contains bastite crystals, a large percentage of magnetite, and about 6 per cent. of alumina; it is clearly the result of the metamorphism of an ultrabasic igneous rock containing olivine.

CASE C.—SOUTH MAYO.

(Map D, Sec. 30.)—The chief igneous mass is the *granitite* of Corvockbrack, made up of microcline, oligoclase, quartz, green or black mica, and magnetite; it is not foliated, but its offshoots of microgranite, rhyolite, and other rocks are often crushed, together with the rocks into which they are intrusive. The sedimentary rocks of this area are seamed by dykes of *felsite*, of which there appear to be two chief sets not differing very much from the granite in age. The sills intrusive into the Mweelrea Beds are *quartz-felsites* or quartz-porphyries, (rhyolites) showing crystals of quartz, orthoclase, plagioclase, and sometimes, under the microscope, a little mica or hornblende, with perlitic, spherulitic, and columnar structures (2895, 7, 8, 2901, &c.). Some of these rocks contain fragments of the sediments through which they have been intruded. About Lough Mask and between that lake and Lough Nafooey, felsites are associated with darker lavas of the composition of *trachytes* or *andesites*, the rocks here being lava-flows bedded with Silurian rocks (2500, 2893). *Diabases* with porphyritic

augite, now converted into uralite (a fibrous modification of amphibole with the external shape of augite but the internal and optical characters of amphibole), occur at Culfin (2502), where a micaceous felsite or *mica-trap* (2902) is also found. *Dolerites* and *basalts* (2496), some of them ancient, others post-Carboniferous in date, occur on the mainland and also on Clare Island (2492). Along the northern slope of Croagh Patrick there stretches a wide band of serpentine (1155), often veined with fibrous chrysotile (1153), or brecciated and re-cemented with similar material (1154). It is associated with massive steatites.

Case C.—The Region of N.W. Galway.

(Map D.)—South of the Silurian belt of Killary Harbour come rocks similar to those of S. Mayo. The Island of Omey and the mainland near it consist of a porphyritic *granite* with pink felspar crystals set in a matrix chiefly made up of quartz, white felspar (often triclinic), with biotite and muscovite (2503); occasionally large white felspars occur as well as the pink ones (2504), and at times the white porphyritic constituent alone is present (2504*a*); sometimes also the white mica is absent. The granite passes locally into *microgranite* and is pierced by veins of *aplite*. The adjoining altered limestones and quartzites are traversed by dykes of *felsite* (2511), *mica diorite* (2517), and *olivine-dolerite*, frequently amygdaloidal (2512, 2903), while *epidiorites* more or less foliated occur in the granite (2514).

Case C.—The Clifden Region.

(Map D.)—The area of schists, crystalline limestones, and other foliated rocks about Clifden is penetrated by a great variety of igneous rocks, amongst which the most abundant are grey *augitic microgranites*, containing plagioclase and porphyritic orthoclase felspars, with augite, quartz, and micas (1886, 2906); these rocks pass into *felsites* (2523) and *quartz-porphyries* generally of a beautiful green colour. *Lamprophyres*, generally of dioritic type (*camptonites*), with idiomorphic crystals of brown hornblende, occur at Lettery (2908), and elsewhere. *Micaceous dolerites* (2526), *epidiorites*, and ultrabasic *amphibolites*, in which biotite is an important constituent (2521), are likewise of frequent occurrence. The *serpentines* and *ophicalcites* of this area are its most characteristic rocks, but as their exact origin has not yet been precisely determined, they have been considered under the heading of foliated rocks (*v.* page 43).

Cases C. and D.—The Galway Granite Area.

Although for convenience of arrangement the specimens from the great granite area of southern Galway have been grouped under several different headings (Leam to the north, Roundstone to the west, and Galway to the south) it is better here to treat

the area as a whole and with it to take the interesting group of rocks on the Cannaver Islands and elsewhere on Lough Corrib. The chief rock is the great *granitite* mass of Galway, many of the varieties of which are very beautiful and in request for polishing. It is generally hornblendic and almost invariably contains two felspars, determined by Dr. S. Haughton to be orthoclase and oligoclase (2940). The colour of the rock is pink, with pink porphyritic crystals of orthoclase or microcline, often of considerable size; frequently a zone of white felspar (oligoclase) surrounds an inner kernel of pink orthoclase (2596), and in microscopic sections plagioclase is found in small crystals inside the microcline, while quartz has been the last mineral to solidify; epidote is generally present and is abundant in some varieties (2598, 2930), and at Mr. Teall's suggestion I have searched the slides for orthite, with the result of finding a mineral very like it in character; mica, though always present becomes much more abundant when signs of foliation make their appearance (2601, 3, 7), or at the edges of the mass where much elongated mica crystals occur in a fine-grained ground-mass (2528, 2538); at times, however, the folia consist solely of quartz and felspar (2609), in which case garnets become an important constituent (2610); considerable quantities of sphene and apatite are present, the latter being in groups consisting of fair-sized crystals. The rock, as usual, passes into and is penetrated by dykes of finer grained rocks of approximately the same ultimate composition, such as *microgranites* (the so-called elvans of the district 2914), *aplites* (2571), *pegmatites*, and *quartz-porphyries*. The microgranites contain porphyritic orthoclase crystals similar to those in the granites (2927, 2933, 2611) and the quartz in them is usually crystalline in shape (2941, 2606). The pegmatites are coarse (2916, 2544) and the felsites vary from dark andesitic types (2542) in which plagioclase crystals are generally visible, to those which are rich in porphyritic quartz crystals (2540).

Very beautiful *quartz-porphyries* occur in the marvellous complex of rocks in Town Park, Galway. They are black (2617), deep red (2616), brown (2942), pink (2615), grey (2624), green (2623, 2548), and white (2640) in colour. Sometimes they show flow-structure (2942, 3, 2626), and the rock breaks up *in situ* into perfect hexagonal columns (1889). The porphyritic constituents include quartz (2942, 2631), orthoclase (2944, 2617), black mica (2643), white mica (1891) and less frequently hornblende (2615, 2944) chiefly in those varieties which contain little quartz (2645). Sometimes the felsites are sheared and foliated, with the development of new minerals on the shear-planes (2628). These rocks appear mainly to be in veins and dykes, but less often they form large bosses in the granitite; the bosses are usually complex in structure and consist of a great variety of different rock types.

By increase in the amount of plagioclase felspar and hornblende, some of which is almost always present, the granitite passes into

quartz-diorite (2553) which is usually devoid of the porphyritic constituents of the granitite. Like the latter they are often foliated (2561). These again graduate into normal *diorites* (2579, 2580, 2649) and *mica-diorites* (2650); some of the latter are doubtless intrusive into the granitite (2652). Dykes of *lamprophyre* are also present, some of them being micaceous (*minettes* or *kersantites*) (2572, 2921), others hornblendic (2578), and it is not easy to draw a line between these and the diorites just mentioned.

Some of the hornblendic rocks appear to have been originally augitic rocks which have undergone subsequent alteration. This has doubtless been the history of the beautiful ophitic rock of Town Park (2659, 2660), and the *epidiorites* have once been dolerites which have undergone a similar change (2550, 2567). Some epidiorites occur in very large masses like that near Leam, and, as is usual, they frequently become foliated and pass into *hornblende-schists* (2570, 2655), often with beautiful crystals of lustrous hornblende (1888) and sometimes with abundant mica (2568, 2647). As is frequently the case in areas of serpentine, coarse *gabbros* (2576) occur in the Cannaver Islands, and in these the augite, though of the platy diallage modification, has escaped transformation into hornblende.

Ultrabasic rocks of several types are found in this area. At Roundstone there are large masses of *hornblende-picrite* consisting of hornblende and actinolite with some diallage, and olivine which has been altered into serpentine (2925). Talcose and hornblendic rocks occur at Leam East (2920), and *serpentines* at Glencraff and Cannaver Island. Those of Glencraff are *ophicalcites* (2911) with veins of chrysotile (2912), those of Cannaver Island true serpentine, clearly derived from the alteration of an igneous rock of the lherzolite type. The rock is often translucent (1189) and very beautiful, but there are many varieties, some containing bastite (2577), others very dark (1191), often brecciated (1192, 3, 2577) and cemented by dark fibrous serpentine or by chrysotile. One variety is made up entirely of radiating fibres of dark, crystallized serpentine (1195).

3.—ULSTER.

I.—GENERAL ACCOUNT OF THE ROCKS.

The Province of Ulster is made up of four very distinct geological parts;—The mountain land of Donegal, Londonderry, and Tyrone; the northern tongue of the Central Plain in Omagh and Fermanagh, very much broken by Old Red Sandstone and still older rocks; the Silurian uplands of the south and east, culminating in the mountains of Newry and Mourne; and the great volcanic

plateau of Antrim. The older rocks lie to the north-east, east, and west, and the newer occupy the great central depression. The following divisions, in descending order, are recognisable :—

Systems.	Series.	Igneous Rocks.
10. Pleistocene, . .	—	—
9. Eocene or Oligocene,	Upper Basalts, ... Leaf Beds, &c., ... Lower Basalts, ...	Intrusive and Interbedded Rocks.
8. Cretaceous, . . .	Chalk, ... Upper Greensand, ...	
7. Jurassic, . . .	Lias, ...	
6. Triassic, . . .	Keuper, ... Bunter, ...	
5. Permian, . . .	—	Intrusive Rocks.
4. Carboniferous, . .	Coal Measures, ... Millstone Grit, ... Yoredale Series, ... Carboniferous Limestone, . . Lower Carboniferous Rocks, .	
3. Old Red Sandstone, .	—	Intrusive and Interbedded Rocks.
2. Upper Silurian, . .	Tarannon Series, ... Llandovery Series, . . .	Intrusive Rocks ?
1. Lower Silurian, . .	Bala Series, ... Llandeilo Series, ...	Intrusive Rocks.
Foliated Crystalline Rocks.	—	Intrusive and Interbedded Rocks.

Cases XXIII.–XXVI., I., II., and XXXII.—Foliated Crystalline Rocks.

As before, it will be well to describe first the foliated rocks of the Mountains, merely for convenience and not by any means as an indication that they are necessarily the oldest rocks in the Province. After them some rocks metamorphosed by the influence of igneous intrusions, such as those of Antrim and County Down, will be described. The rocks will be treated in the following divisions :—1. The area of *North-east Antrim* ; 2. *Donegal, North-west* of the Barnesbeg granite ; 3. *Donegal, South-east* of the same granite ; 4. The area from *Moville to Raphoe* ; 5. The *Derry* region ; 6. The area of *Pettigo* ; 7. That of *Tyrone* ; 8. Products of *contact-metamorphism*.

Case XXIII.—The Antrim area (Map F; Sec. 2; P. 63, 74). This small district of foliated rocks extends from Murlough Bay to Slieve-a-norra, but as the only rocks in contact with them are not older than the Old Red Sandstone and Carboniferous Systems, the only guides to their age are lithological characters and a comparison with the rocks on the opposite shores of Argyllshire, neither of which can receive implicit reliance. The chief rocks are *schists* or *gneisses*, which may be altered *grits*, consisting of rounded crystals of felspar or quartz grains with foliation planes of mica (820, 2), extremely dense *chlorite-schists* (1047), and very coarse, black, crystalline *limestones* (605, 7), sometimes penetrated by red felspathic veins (608), and resembling the limestones which occur in a line with them in the Mull of Cantire and in Derry to be presently alluded to. There are also foliated igneous rocks including *epidiorites* in this area (*v.* P. 74).

Case XXIII.—Area North-West of the Barnesbeg Granite (Map E, Sec. 26; P. 55, 78, 91, 82, 88). The rocks here are often merely altered sediments such as *quartzites* (967), which sometimes show those linear structures, due to stretching and folding, which Mr. Kinahan has aptly termed "mullion structure" (1059); these are sometimes micaceous (1061), and pass over into *quartz-schist* (1062); they are interbedded with *slates* (1067), actinolite and hornblende-*schists* and *phyllites*, which often contain staurolite (1049) and andalusite (823), crystalline *limestones* either pure and compact (965) or else dolomitic (963), and containing crystals of garnet (584), actinolite (970), mica (962), tremolite and idocrase (584). These minerals are developed where the limestone occurs in junction with, or enclosed in, the granite, and where it has been highly metamorphosed A remarkable rock called by Mr. Scott "*sphene rock*" occurs at Annagarry, and in the granite near the limestone of Barnesbeg Gap; it contains orthoclase, green pyroxene, sphene, apatite, and sometimes scapolite. Sterry Hunt compared this sphene rock to that associated with the Laurentian limestones in Canada, and his description appears to indicate that the rock occurs at the junction of the limestones with the gneiss. In the schist patches enclosed in granite sillimanite, andalusite, and kyanite are developed. One of the most interesting bands in this series of rocks is a great *boulder-bed* (689, 691, 2) extending for many miles and containing fragments of granite (1053, 4), and other rocks in a matrix consisting of crystallized minerals. The quartzite of Muckish is felspathic, and decomposes into a loose quartz sand, once much used for glass making in consequence of its extreme purity. Fine grained *gneisses*, possibly modified granites, occur at Bloody Foreland (1048).

Cases XXIII. and XXIV.—Area east of the Barnesbeg Granite (Map E; Sec. 26). A set of rocks somewhat similar to those last described stretches over a wide range of country from Malin Head to Donegal Bay; it is even possible that they may be the same rocks repeated by a fold. The *gneisses* are for the most part

foliated granites (1050, 2801, 3). The *mica-schists* are generally much crumpled (936), the larger folds being crossed by a minute puckering almost at right angles to their direction (1069), and sometimes an appearance of a double foliation is to be seen (1094). The intensely indurated *shales* of Fintown have yielded pyritous markings which are like the relics of Graptolites, a point which, if satisfactorily established, would give precise information as to the age of the bands in which they occur, and possibly of the entire series of foliated rocks (v. case 1, and page 109). Other *slates* contain chiastolite (1070), and andalusite (2792), while *schists*, composed chiefly of kyanite and sillimanite are not uncommon near the granite masses. These minerals, together with the structure of the knotted schists (1071), show the important influence in this area of contact metamorphism of a type similar to that produced by the contact of plutonic rocks. *Quartz-schists* (1077), the *boulder-bed* already described (691, 2), *limestones* with garnets (957) idocrase, sphene (956), and a green mineral probably diopside or some other form of pyroxene (958), *saccharoidal marble* (953), *pebbly* (819) and *sheared* (592) *limestones*, *ophicalcites* (1074), *dolomites* (591), *anthophyllite rock* (1898), and *soapstone* (1075) are amongst the principal constituents of this remarkable series. The white marbles are capable of an excellent polish, and can sometimes be raised in large blocks; the soapstone and its allied "cam-stone" have been quarried for lubricating purposes. Similar rocks extend to the Barnesmore granite area (1460, 5), and about Castlederg there are crystalline (1587), dolomitic (1582), and micaceous *limestones* (943) penetrated by epidiorites and hornblende schists.

The crystalline limestones of Culdaff are of importance from the fact that they contain radiating masses of calcite which have been considered by Professor Hull and others to be Corals. They, however, do not present any absolutely indisputable evidences of organic origin, and are not more like Corals than many of the purely inorganic concretions which crowd the Magnesian Limestone of Durham. Several specimens of these supposed corals will be found amongst other doubtful fossils in case 1. More recently, Professor Sollas has detected bodies which may possibly be the remains of Radiolaria in the same limestone (*v.* page 109). Some of the photographs (P. 78, 82, 85, 86, 87, 88) represent cliffs formed of the different foliated rocks of Donegal.

Case XXV.—Area of Moville and Raphoe. This area is really an integral part of that last described. In it are found frilled *phyllites* (1086), *chloritic schists* (1085), workable *slates*, still showing the bedding planes crossed by those of cleavage (1092, 3), and some in which the cleavage planes have been contorted (1087), *quartzites* (1084), *quartz-schists* (1081), *grits* (1088), coarse grits or fine *conglomerates* with rounded and crushed fragments of quartz and felspar in a schistose matrix (947, 9), and dark-coloured crystalline *limestones* (941).

XXVI., XXXII.]

Cases XXV. and XXVI.—Londonderry Area (P. 85, 86, 87). Much of this county is formed of *mica-* (1112), *quartz-* (1114), and *chlorite-schists* (1400) with sheared *grits* (2813), like those of St. Johnstown and Raphoe. About Dungiven there are extremely coarse, black, crystalline, *limestones* (1389), which continue the line of similar rocks from Cantire to Murlough Bay. The little area of Omagh, divided from the last by a Carboniferous outlier, contains similar schistose *grits* (1539), *graphitic schists* (1541), and, near the town of Omagh, a curious set of *talcose* rocks which may possibly be metamorphosed igneous products (1550).

Cases I. and II.—The Area of Pettigo. For want of space at present the foliated rocks from this region have been placed with other *recent acquisitions* in cases I. and II. They are now delineated on the Survey maps as of Archæan age, the evidence being partly their lithological character which links them with the "old gneiss" of the north-west Highlands of Scotland, and partly their position below schistose rocks of the sedimentary types already described. It may be pointed out, in passing, that these schistose rocks extend unbroken over the country to Derry, where they come within a few miles of the unaltered rocks of Pomeroy and Desertcreat. These unaltered rocks contain Lower Silurian trilobites like *Ogygia*, *Trinucleus*, &c., which have been identified and figured by Portlock. Such contiguity would seem to indicate that the schistose series are likely to be at least older than the Llandeilo rocks, a conclusion which must inevitably push back to Pre-Cambrian time the age of any rocks deposited before them, and separated from them by an unconformity.

The Pettigo rocks are coarse hornblendic *gneisses* (516), contorted *granulitic gneisses* (520, 4), often full of garnets (518) and occasionally showing adventitious minerals like molybdenite (1103), felspathic *eclogites* which contain garnets and green pyroxenes with a certain amount of felspar (522), garnetiferous *amphibolite* (534, 560), and *schists* and *gneisses* containing three or more of the following minerals—felspar, quartz, hornblende, biotite, muscovite (523, 7, 531). These are penetrated by diorites, epidiorites (517, 1109), and pegmatites (1105, 8), the latter being the source of the kaolin used in the manufacture of the finer sorts of porcelain made at Belleek. On their northern boundary these rocks, which have all the characters of a foliated plutonic complex, are covered by *flaser-schists* containing lenticles of quartz which may once have been pebbles (561), *phyllites* (566), and pebbly *schists* (572).

Case XXXII.—The Tyrone Area. A two-fold series similar to this occurs also in Tyrone, but the plutonic and foliated rocks are rather more varied and contain *breccias* and what seem to be other volcanic products. The foliated rocks are placed in case XXXII. devoted to recent acquisitions, and include *gneisses* (1117), *breccias* (1527), and silvery *mica-schists* (1523), containing garnet (1517), hornblende (1516), and andalusite (1520).

Case XXVI.—Products of Contact Metamorphism (Map F). The rocks altered and crystallized by the undoubted action of intrusive masses of igneous rocks are placed in sequence with the foliated rocks in case XXVI. The intrusive dolerites of Antrim show the effect of contact-action on all types of sediments. Sandstones are indurated (971), Carboniferous and Liassic clays baked into *porcellanite* (636, 624) and *lydite* (831), and Chalk converted into *crystalline limestone* (628), (D. 28). This marble is an extremely interesting rock, and is as coarsely and thoroughly crystalline as most ancient marbles, although no minerals other than calcite appear to have been developed (972, 6, 9). The flints are converted into a red jasper-like rock, whether actually enclosed in the basalt (637), or in the flint gravel which has been intruded upon by the rhyolite (977). The basalt intrusion to the south of Ballyshannon has hardened and altered the Yoredale shales and sandstones which surround it (1504). The intrusive granite mass of Crossdoney has altered the grits, sandstones, and shales which border it into purple *lydite* (1559), *hornfels* (1571), and *mica rocks*, consisting of granulitic quartz, associated with numerous flakes of a rich, warm-brown mica; it has not however generally produced any marked foliation, nor even in all cases destroyed the bedding planes; however, no other original fragmental structure can be now detected in the microscopic sections of the rocks.

Contact alteration also occurs round the other great igneous masses in Ulster, especially the granites, but these instances have not yet been studied or described in any detail. The Mourne granite has merely baked and hardened the rocks which surround it without effecting any great mineral change. On the other hand the Newry granite has produced an aureole of metamorphism extending from half to three-quarters of a mile from its boundary. Mica is first developed, then it becomes more plentiful and larger, until the rock passes into a *mica-schist*, whose junction with the granite is quite sharp.

Case XIX—The Silurian System.

(Sec. 1, P. 82).—The rocks of this system are found in a broad band sweeping from the coast of **Down** through **Monaghan** into **Cavan** (P. 70). This region is practically an extension of the Southern Uplands of Scotland, with which it agrees in its complicated structure of close packed anticlinals, and in the general nature of the rocks. The anticlines display Bala and even Llandeilo rocks, the synclines are filled with the more recent deposits of the Upper Silurian System. Towards the north the sedimentary rocks are penetrated by numerous dykes of diabase and mica trap, and consist of grey, purplish and greenish grey *grits*, often micaceous, with *flagstones*, *conglomerates*, and some *slates* and bands of dark graptolitic *shales* at several different horizons. Mr. Swanston and Professor Lapworth by the examination of these organisms on Belfast Lough and the shores to the east have been

able to establish subdivisions of the graptolite bearing shales. Messrs. Clark and Peach have traced four divisions as far as Hillsborough and the three lower divisions into County Armagh. They have also detected the fifth and highest zone noted below. These divisions are given in descending order:—

5. *Beds 6 miles N. of Tieveshilly,* 4. *Black Shales and Flags of Tieveshilly (Exiguus zone).*	= Tarannon Series.
3. *Coalpit Bay Beds (of Lapworth).*	= Llandovery Series.
2. *Black Shale of Carnalea and barren Sandstone of Coalpit Bay.*	= Bala Series.
1. *Shales of Ballygrot and Craigavad.*	= Lower Bala and Llandeilo Series.

The Ballygrot Beds contain *Leptograptus, Cœnograptus, Dicellograptus, Didymograptus;* the Carnalea shales, *Climacograptus, Diplograptus, Lasiograptus;* the Coalpit Bay Beds *Rastrites, Monograptus gregarius, Diplograptus acuminatus, D. vesiculosus, Cephalograptus cometa,* and *Retiolites;* while the Tieveshilly Series has yielded *Retiolites* and several characteristic species of *Monograptus.* The rocks are much contorted, crushed, and cleaved, and it has been noticed that the cleavage makes a higher angle with the bedding in coarse than in fine grained bands. As is not unusual, the black shales have been supposed to contain coal seams, and numerous shafts have been sunk into them in the vain hope of winning coal. The rocks do not vary much in character when traced to the south west as far as Cavan, but beds of *conglomerate* from eight to fifteen feet thick become an important factor in the series (one of these, that of Granard, has been already described under Leinster, *v.* page 19). Examples of *grit* (1355, 1323), *conglomerate* (1326) and *shale* (1322) will be found in the cases (*v.* p. 56). Great intrusive masses of plutonic rock, like the granitite of Newry, and that of Crossdoney, near Cavan, were intruded into these rocks in post-Lower-Silurian and possibly in some cases in post-Upper-Silurian (Devonian) times, and at a later date masses of not less importance like the granites of Mourne and Slieve Gullion, with their associated complex of other igneous rocks (*v.* page 75, &c.). These intrusions have produced a very marked contact alteration in the sedimentary rocks which border the granites both in the Newry area and at Crossdoney (*v.* page 60).

An isolated patch of Silurian strata at **Desertcreat,** near **Pomeroy,** is of great interest owing to the number of fossils from it described by Portlock. Whilst the lower beds contain an undoubted Lower Silurian fauna, the upper beds yield Graptolites which have enabled Lapworth to correlate them with the Lland-

overy or Tarannon rocks. They are chiefly green, fossiliferous, *slates* occasionally passing into argillaceous *limestone* (801), interbedded with flaggy *sandstones* and *conglomerates*. About **Lisbellaw** in Fermanagh both Lower and Upper Silurian rocks have been mapped. The Lower are hard splintery *slates*, red or greenish in colour (1415), with some bands of *conglomerate* and fine grained *greywacke grits* used as a local building stone (1408); the Upper are very massive *conglomerates* with well rounded pebbles, varying from half an inch to a foot in diameter, of quartzite, granite, and vein-quartz, with blue quartz (1416) in the matrix; it is apparently from beds associated with the conglomerates that Graptolites of Llandovery affinities have been obtained.

Case XIX.—The Old Red Sandstone.

This division is found bordering the ancient rocks of north-east Antrim, cropping out from under the lower Carboniferous rocks of Londonderry, and spreading over a hilly, fertile country between Pomeroy and Enniskillen, where it has been coloured as "Dingle Beds" in the Survey maps.

About **Cushendall** (Map F, Sec. 2) there are massive *conglomerates* of vein quartz and quartzite, replaced almost completely by pebbles of quartz-porphyry (613), where they rest on an old mass of that rock; passing inland, sand beds (609,610) make their appearance in the Series though its base still remains pebbly. The old sea caves about Cushendun and Cushendall are excavated in this conglomerate, and a view of them is displayed in the Museum (P. 79). The tract between **Pomeroy** and **Lough Erne** shows a basal *conglomerate* near Omagh, made up chiefly of the debris of the underlying schists, pebbles of soft mica-schist being set in a matrix loaded with mica powder, derived from the same source (1531). The bulk of the rocks are red, purple, and brown micaceous *sandstones* (1545), overlaid towards the centre and south by *conglomerates* (1547), containing fragments over one foot in length. **South of Pomeroy** there is a large exposure of porphyrite lavas and ashes (*v.* page 74) which appear to be banded with the lower beds of the Sandstone, together with some intrusive masses of ancient altered basalts, while more recent dolerite dykes, possibly of Tertiary date, often traverse the sandstones in straight lines extending for many miles. It is noteworthy that many of the grit beds put on the aspect of ashes. Near **Lisbellaw** gritty *sandstones* with fragmental quartz, felspar, and muscovite (1410) are associated with *conglomerates* of similar composition (1411).

A patch of chocolate-red *conglomerates*, *sandstones*, and sandy *shales*, probably of this age, was discovered by the Geological Survey on the **Fanad** promontory. The pebbles are chiefly of granite, quartz-porphyry, diorite, and quartzite, and have been derived from the older series, from which the beds are separated by a thrust plane.

CASE XX.—THE CARBONIFEROUS SYSTEM.

The Lower Carboniferous Sandstone.—The rocks of this age in North East Ulster are largely covered by the immense lava plateau of Antrim and only appear at its edges or where denudation has perforated it. It is the Lower Carboniferous rocks that are chiefly seen (P. 70) and these have a peculiar character not elsewhere known in Ireland, but one which links them with the Scottish beds of the same age, and has led to their being termed *Calciferous Sandstone*. The beds consist of *sandstones* (619,907), white (614) yellowish and red in colour, with *shales* (868), thin *limestones* (908), several seams of *coal*, and one of black-band *ironstone*. Where fully represented the measures contain five seams of coal, of which the "Main Coal" is 4 feet thick; several of these have been worked near their outcrop. The sandstones give a beautiful building stone when carefully selected.

The coal beds are sometimes overlain by the basaltic lavas, and are frequently penetrated by dykes and sills (or intrusive sheets), of which that of Fair Head, rising 636 feet above the sea, is the most magnificent example. The basin of Lough Foyle occurs in a trough of Calciferous *Sandstone* (1376), *conglomerate* (3485) and red or yellow *shales*, occupying flat ground below the more rugged and hilly country of the schists.

On the west of L. Neagh this series is divided into a Lower and an Upper member, of which the former consists of red *sandstones* (623) and *conglomerates*, the latter of whitish and pink *sandstones* (1353) which yield good building stones and flags, coarse *grits* with quartz pebbles, blue calcareous *shales*, and bands of impure *limestone*. No coal seams of any value occur here, only mere partings of carbonaceous matter, but there is a seam of red ferruginous clay containing hæmatite and a small quantity of manganese ore.

North-west of Omagh the Lower Carboniferous Sandstone is arenaceous (1542, 946) towards the West, but becomes more argillaceous (901) towards the East; both Lower and Upper Stages appear to be represented, and south of the great Old Red Sandstone tract of Tyrone, the lower part is sandy while the upper part consists of shale. An interesting *oolite* with large sandgrains slightly coated with calcite occurs near Cookstown (1372). Passing to the south-east these basement beds appear to thin out, and the Lower Limestone in Monaghan and Carrickmacross rests directly on Silurian rocks without the intervention of a sandy base, while at Dundalk such a base is only very thin. In Cavan there are thin *sandstones* and *flags* with a *conglomerate* at the base (1553, 1565), and at Cultra (Sec. 1) on Belfast Lough a pale *limestone* in this series is characterised by abundance of *Modiola Macadami* (*v.* page 115) (1039).

In Donegal this Series is represented by 2,000 feet of massive coarse dark red and purple *conglomerate* (1456) succeeded by *grits* and *flags* (1453), and dark calcareous shales with plant remains (1484). Two remarkable outliers of similar rocks are found on

the summit of Slieve League. Further south, at Ballyshannon there is a *dolomitic rock* at the base (1492) which usually forms the matrix of a *conglomerate* (1488, 1490) full of fragments of quartz and granulite derived from the ancient subjacent rocks.

The Lower Carboniferous Limestone.—In Donegal the Lower *Limestone* is dark grey (1486), shaly and sandy in the upper beds, and becoming more shaly towards the north; to the north-west of Omagh, too, there is more sediment towards the north and less towards the south in a series about 600 feet thick which is often richly fossiliferous. Some of the limestones here are rich in magnesia without having the usual appearance of dolomites. About Upper Lough Erne the limestone is bluish grey and subcrystalline, and contains many Brachiopods (P. 71); whilst at the east of Slieve Beagh it is often coarsely crystalline. The Lower Limestone of Cavan has a smooth fracture, is dark grey in colour, and is often earthy and fetid (1552); that of Armagh contains thick beds of pale subcrystalline *limestone* (1337) which furnishes the *marble* quarried there, a pink (1348) or purplish brown stone spotted with yellow and brown, the colour being possibly due to staining from the overlying beds of Permian sandstone; to the west and north-west of Lough Neagh the rocks of this division are thin-bedded and light grey (945), often earthy and impure, occasionally oolitic, fossiliferous (902), and coralline (1369, 1373, 944). The Carboniferous Limestone of Donegal is illustrated by the photographs 55, 91, 92.

The Middle Carboniferous Limestone.—This Stage is uniform in character and consists of calcareous *shale* (1495) and beds of massive *sandstone* (904), and *flags*, with occasional seams of limestone, generally thin and impure (1428, 1487, 905), and sometimes cherty (1498, 9). In Donegal the *sandstone* provides the celebrated Mount Charles building stone much used in the construction of the Museum of Science and Art; similar stones for building, with others for flagging, are obtained from a bed in this Stage in Derry and Tyrone. The stones are open in texture, creamy in colour, felspathic and micaceous, with a siliceous cement. They are not difficult to work and are durable (Y. 260). West of Lough Neagh there is good hydraulic *limestone* and seams of *clay-ironstone*, and about Upper Lough Erne the subdivision is 1,000 feet in thickness.

The Upper Carboniferous Limestone—This Stage, generally much purer, more or less crystalline (698, 1360), with *chert* bands and layers of *dolomite*, broken up by conspicuous joint planes into square pillar-like blocks near Omagh, occurs in massive, thick beds, forming the slopes of an escarpment about Upper Lough Erne. About Cookstown and near Lough Neagh, where the whole thickness of the Carboniferous Limestone amounts to 2,000 feet, important bands of *sandstone* and *conglomerate* occur in the Stage.

The Yoredale Series usually consists of *shales* and fine calcareous *grits* with thin *limestones* (1512) below them, followed by felspathic *grit* (1496) and *sandstone* (1507), often with concretionary iron-stained lumps, and occasionally nodules of *clay-ironstone*. On Upper L. Erne (Lisnaskea Mountains) and Slieve Beagh, however, the *sandstones* form the lowest member (1423, 1425), and are followed by calcareous *shales* in which are nodules and beds of *clay-ironstone*, formerly smelted, and slight indications of utterly worthless *coal*. The series varies from 300 feet thick near Omagh to 600 feet near L. Neagh.

The Millstone Grit.—This rock, where met with, is as usual a coarse-grained quartzose *grit*, occasionally *conglomeratic*, sometimes massive, but often sufficiently flaggy to be used for paving. It is 200 feet thick near L. Neagh.

The Coal Measures.—The area occupied by this series near Lough Neagh is probably one of the most important in Ireland, as the coal seams are numerous and fairly thick. The measures have been divided into two parts, the Lower or Gannister Stage, 1,000 feet, and the Middle Stage over 900 feet thick. The Lower Stage contains near its base two workable *coals*, the "Main" and the "Little" seams, embedded in *sandstone*, *grit*, and hard sandy *shale*, which contains marine fossils such as *Bellerophon*, *Orthoceras*, *Goniatites*, and *Spirifera*.

The Middle measures contain eighteen *coal seams* which have been extensively, but not very systematically, worked. The Annagher seam is 9 feet thick, four more average 5 feet each, while the rest vary from 2 to 3 feet in thickness, there being two seams of valuable *cannel*, one 22, and the other 14 inches thick. Some of the coals contain as little as 2 and others as much as 18 per cent. of ash. Occasionally the seams are "washed out" and replaced by "horses" of sandstone.

The associated strata are *fireclay*, soft *shales*, and *clay-ironstone*, and yield remains of fossil Plants, Shells, and Fish. The ironstones contain from 21 to 35 per cent. of metallic iron.

Case XX.—The Permian System.

(Sec. 1).—The Province of Ulster contains the only known Permian rocks in Ireland, although a suggestion has been made that some of the dolomite "dykes" in the Carboniferous Limestone may have been filled from above in Permian times, while it is certainly not unlikely that the transformation of some of the limestone into dolomite may have been effected by the waters of the salt lakes in which the Permian strata appear to have been formed. The rocks are only found at three spots. Near Tullyconnel there are yellow and flesh-coloured *dolomites* (803), often looking tufaceous (1362), sometimes oolitic, weathering like sandstone and full of typical Permian fossils; the cavities in the rock frequently contain gypsum. Similar dolomites, formerly

quarried for the manufacture of sulphate of magnesia, are met with on the east side of Belfast Lough. At Armagh a patch of Permian rock rests unconformably on the Carboniferous strata, and consists of beds of *breccia* (1339, 1343) and *conglomerate* about 17 feet thick, covered by a *boulder bed* containing blocks of grit and quartzite. These rocks present considerable resemblances to the Permian strata of northern and midland England.

Case XXI.—The Triassic System.

(Map F; Secs. 1 & 2).—This system is divisible into a Lower part, mainly of sandstone, called the Bunter, and an Upper one, chiefly of marl, called the Keuper. The strata appear to have been formed in lakes similar to those in which the foregoing Permian rocks were laid down.

The Bunter—The lower division may be seen to the west and south of Lough Neagh, near Belfast (P. 71), occupying the great depressions of Belfast and Strangford Loughs; a small patch also enters the Province from the Kingscourt area. Everywhere the rocks consist of bright red or orange coloured *sandstone* (805), often marly (807, 1311), sometimes mottled (1357), and sometimes yellower in tint, and with partings of mottled *shales* or *marls* (1366). Occasionally the surface of slabs is marked with ripples, suncracks, prints of salt crystals or tracks of animals; the only signs of life met with in the Series, except the bed of fish remains, containing *Dictyopyae* (*Palæoniscus*) *catoptera*, which occurs at Rhone Hill near Dungannon. About Belfast (P. 71) it is much penetrated and metamorphosed by dykes of Tertiary dolerite (P. 60), and although usually occupying flat ground it rises, where protected by a covering of Tertiary lavas, into considerable hills, like that of Scrabo (D. 44; P. 89, 90). The red sands are used as a local building stone, and the grey and red sandstones of Scrabo Hill provide freestones (396) and flagstones which are durable if well selected. Gypsum occurs in Monaghan (806).

The Keuper (Sec. 2).—This series, as usual, frequently overlaps the margin of the Bunter series and rests directly on older rocks, particularly in Londonderry and Antrim. Where the full thickness is present there is a *sandstone*, white, brown, or purple, loose and pebbly (618), at the base; then follows a great mass of red, purple, and greenish marls, sometimes showing pseudomorphs of rock-salt (830), and over 750 feet thick about Belfast, where they were pierced by a boring which passed through some three seams of rock-salt and gypsum, giving 150 feet of saliferous strata. Salt has also been met with near Larne, and gypsum near Kingscourt. The strata are unfossiliferous.

The Rhætic Series (Sec. 2).—These transitional strata, between the lacustrine beds of the Trias and the marine clays of the Lias, are met with near Lough Foyle, to the north of Larne, and near Belfast. They are light green and grey, slightly calcareous, *marls*,

followed by dark-bluish arenaceous *shales* (910), and *limestones* (809), containing the usual brackish-water fauna, including *Avicula contorta*, which sometimes makes up whole beds of limestone. The Series is never more than 100 feet, and seldom over 20 feet in thickness.

CASE XXI.—THE JURASSIC SYSTEM.

The Lias (Sec. 2).—This Series consists of stiff blue fossiliferous *clays* (626, 810), black indurated *shales* (841), and blue *marls* interstratified with dark *limestone* (811, 832, 5, 1041). About Larne the following zones in ascending order are recognisable :— *Ammonites planorbis*, *A. angulatus*, *A. Bucklandi*, and possibly *A. margaritatus*. The total thickness amounts to 35 feet. Near Portrush the clay is much baked by the intrusion of basalt (*v.* case XXVI.)

CASE XXI.—THE CRETACEOUS SYSTEM.

The Upper Greensand (Map F; Sec. 2; P. 69).—A great gap occurs at this point in the sequence, and the succeeding deposits are the lithological and homotaxial equivalents of the Upper Greensand of eastern and southern England, although probably they are later in actual date. The basal bed is usually pebbly, and a *conglomerate* a foot in thickness is often met with. This passes into a compact *sandstone* speckled with dark green grains of glauconite (812), which, becoming oxidized, give the upper beds a reddish colour near Larne (836, 7). Only 10 to 12 feet thick here, and occasionally dwindling to a few inches in the north, it thickens out to 70 or 80 feet near Belfast, where there are green *marls* and *sands* (813, 872) surmounted by a *conglomerate* known as the "mulatto stone." Dr. Hume and M. Barrois conclude that the Hibernian Greensand was not deposited contemporaneously with the English rock of the same name, but was laid down in Lower and Middle Chalk time near the shore of the Chalk Sea.

The Chalk (Map F; Sec. 2; D. 24; P. 59, 64, 73).—This is great mass of hard white, compact *limestone* (632) occasionally marly and ironstained (633, 627), and with seams of *flint* about four feet apart (814). The organic origin of the Chalk is clearly seen in microscopic sections which are full of foraminifera from $\frac{1}{100}$ to $\frac{1}{1000}$ of an inch in diameter, and similar tests have been found by Mr. Wright in the siliceous dust inside the hollow flints. The flints themselves (635, 8) are tabular or irregular bodies made of almost pure silica; they have an abrupt junction with the Chalk, and have almost certainly been deposited in it from solution of silica in water, as shown by the replacement in flint of organisms which while living undoubtedly possessed shells made of carbonate of lime. Where the Upper Greensand is absent there is a pebble bed which forms a base to the Chalk (640, 1, 2, 3), clearly indicating that we are here near the margin of the Chalk Sea. Separating the Chalk from the

overlying basalt of the plateau there is generally a gravel made of flints (639) which are often reddened and altered by the heat of the basalt when it flowed out on the surface (D. 13, 23). The fossils in the finer beds of this stratum are mainly rolled forms derived from the Chalk. The Antrim Chalk is about 150 feet thick; it forms a base to the plateau, but occasionally it rises into important hills when protected by a capping of basalt. It appears to belong to the division of the Upper Chalk, and mainly to the highest zone characterized by *Belemnitella mucronata*. The hardened nodular bands indicate the presence of a shore line, while the transgressive overlap to the south, as M. Barrois has pointed out, indicates that in all probability this shore line was situated in the direction of County Down.

Case XXII.—The Tertiary Group.

The Volcanic Rocks of Antrim (Map F; Sec. 2).—After the denudation of the Chalk and previously formed strata the north-east of Ireland became the scene of wide spread volcanic activity. The earlier or lower sheets of Basalt amount to 450 feet in maximum thickness and, resting on an eroded surface of Chalk, rise into tabular hills 1,200 to 1,300 feet in height, while the valley sides are terraced by the outcrop of the great sheets of lava which have been carved away by streams since early Tertiary times (D. 34; P. 73, 74, 76). The lavas exhibit tabular, spheroidal (D. 18), and columnar jointing (D. 31; P. 52, 53, 56, 64, 67, 72); their general character will be described on page 78. Occasional beds of agglomerate and tuff occur, and the old vents of eruption, filled with masses of coarse agglomerate penetrated by basalt dykes, may occasionally be made out, as at Carrick-a-Raidhe and Tieveragh Hill (P. 71, 74). Masses of *Rhyolite* occur at Tardree and Templepatrick, Ballymena, and near Moira, and are intrusive into the *Lower Basalts*. They were probably exposed to denudation before the *Upper Basalts* were laid down, for beds of rhyolite gravel are found between the Upper and Lower Basalts.

The Associated Sedimentary Deposits (Map F; Sec. 2).—Between the layers of the Lower Basalt bands of *clay* and *iron-ore* are of frequent occurrence (D. 32), but they become of great importance between the Upper and Lower set of Sheets (D. 13, 23, 24, 27; P. 59, 68). They consist of basaltic *ash* beds (1042, 3) and trachyte *gravel* (980, 1, 3) passing down to fine clay, often full of fossil plants (984, 5) and seams of lignite as at Ballypalidy, famous for its leaf-bed, and to *bauxite* (839, 988, 990), a clay rich in hydrated oxide of aluminium with some iron, sometimes used in the preparation of the former metal. Mr. Kinahan names the slightly ferruginous clays *Alumyte;* they contain 42–52 per cent. of alumina, 1–1·5 of iron oxide, 13–27 per cent. of silica, and 18–27 per cent. of combined water; consequently, as he points out, they do not correspond with any of the principal types of

French bauxite, but resemble more the wocheinite of Carniola. At other times there are bands of *clay* (D. 29), and *lithomarge* (987), passing into *ochre* and then into a rich *iron-ore* (D. 48). This is sometimes a clay saturated with hydrated iron oxide, but often the iron is gathered into pisolitic concretions of hæmatite in an ochreous paste (993, 5, 8, 9). The iron ores contain from 35 to 40 per cent. of metallic iron, and are worked still to some extent, while the ochre is extensively used. There is little doubt that this series of deposits represents the subaerial denudation of the older volcanic rocks; it was deposited from streams, lakes, and the soil, and was afterwards covered up by the flows of Upper Basalt. The plants referred to above indicate that the volcanic activity probably dates to the late Eocene or Oligocene period.

The Pipe clays of Lough Neagh which have been considered to be Pliocene in date are either the expansion of those just described or else earlier than the Basalts in date. Their relation to the Basalt is uncertain, but they probably underly a great deal of the area of Lough Neagh. They are white *clays*, sometimes useful as a pipe-clay, variegated by red and greenish mottling (2789), and containing fossil plants usually preserved in carbonaceous material, but occasionally partly converted into silica. Silicified wood is very common on the shore of Lough Neagh and has been widely dispersed by glaciation (*v.* case 50). This wood opal resembles that preserved in the basalt of the Giant's Causeway, from which it was once supposed to have been derived, but Mr. Swanston has now proved beyond doubt that the Lough Neagh clays have been its source. The clays containing *Mytilus* (once referred to *Unio*) have been shown by Mr. Clement Reid to contain scratched fragments of basalt and worn fragments of silicified wood; they underlie other boulder-bearing clays, and must be classed with the Pleistocene deposits.

CASE XXII.—THE PLEISTOCENE SYSTEM.

The Lower Boulder Clay.—The North of the Province of Ulster it is which gives the best evidence of two directions of main glaciation, the first from S. or S.E. to N. and N.W. outwards from the great snow field which extended south-westward from Belfast and the second from N.E. to S.W. when the Scottish ice invaded the coast of Antrim and travelled across the country and out by the western coasts. The Lower Boulder Clay (D. 25; P. 73), the product of this glaciation (2790), extends in ridges and sheets to heights like 1,300 feet in the Sperrin Mountains and elsewhere. Shells are found in the clay at Muff and Bovevagh, and the clays are at times useful for brick-making.

The Middle Sand and Gravel is current-bedded and shell-bearing, and occurs in terraces up to 600 feet above the sea in Antrim.

The Upper Boulder Clay, well developed in Tyrone, is sometimes 50 feet in thickness and extends to a height of 850 feet. The

gravels of some **eskers** are apparently covered by Upper Boulder Clay and many have erratic blocks on them. Some of the erratics are very large, as for instance the "Butterlump" Rock on the east coast of Down which measures 20 feet by 15 by 15; a picture of this by Du Noyer will be found on the walls (D. 45), and also a photograph (P. 79). Another block has the same breadth and height but is 30 feet long (see also P. 84). There are **local moraines** in many places, for instance in the Mourne Mountains and on the granite range of Barnesmore, and some of these moraines dam up existing lakes or others which are now filled up with detritus and form alluvial flats.

There are **Raised Beaches** at heights of about 25, 50, and 75 feet above mean sea level with old raised cliffs and sea stacks (P. 57) above the highest tides of the present day. In connexion with some of these beaches **kitchen-middens**, or old refuse heaps of shells, bones and charcoal, associated with flint implements and chips of undoubted human workmanship, have been obtained, and in some of the high level river gravels palæolithic flint weapons have been discovered. Mr. Praeger considers that the **Estuarine clays** found beneath the sea level on many of the shores and in the Loughs of the North of Ireland were formed by the depression which gave rise to the highest of these beaches. Resting on the Boulder-clay comes, first of all, red sand which is considered to be equivalent to the eskers; then grey sand and peat containing remains of *Megaceros* (the "Irish Elk") and probably equivalent to the shell marls so frequent under peat bogs and marked by containing *Megaceros;* then follow the clays, the lower characterised by *Scrobicularia piperata* with a littoral shell-fauna, and hence not deposited in deep water, and the higher deposited tranquilly in deeper water and yielding *Thracia convexa* and other shells which indicate a depth of 50 to 80 feet. The fauna is of a slightly more southern type than that inhabiting the shores at the present day.

The **river alluvia** yield brick-clays, and that of the River Bann contains numerous diatoms, and is so siliceous that it is mixed with clays for brick making. Blown sand, intakes, and travertine deposits also occur. The bogs are wide-spread, sometimes yield bog iron-ore, and occasionally conceal the relics of old lake-dwellings or crannoges in which stone and bronze implements, and sometimes gold ornaments, have been found.

2.—THE IGNEOUS ROCKS OF ULSTER.

The Northern Province is unrivalled in Ireland for the quantity and variety of igneous rocks which it contains, all types being represented, from the most ancient and foliated types, to the most recent volcanic outpourings in the British Isles. Case F. is reserved for the known Tertiary lavas of the great Antrim plateau, with a few older rocks from the same district, and the rest of the igneous rocks are placed in case E. For this reason

it will be necessary to depart somewhat from the usual order of description from North to South, in order to treat the great crystalline areas of the West first; we shall then proceed towards the East and South, and conclude with a description of the Tertiary and older rocks of Antrim and the neighbourhood. Such a description cannot however be strictly historical, for even in the areas of most ancient rocks, there are found others of much more recent date, including even Tertiary, or at any rate post-Carboniferous, dykes. The following areas will be dealt with:—(1) *N. W. Donegal*, (2) *Barnesmore* and the *Blue Stack Mountains*, (3) *the Raphoe* region, (4) *Crew and Park* in Derry, (5) *Slieve Gallion* in Tyrone, (6) the rocks in the western and central tracts of *Old Red Sandstone* and *Carboniferous rocks*, as at Omagh, (7) the *Coast of Down*, (8) the granite areas of *Newry and Slieve Gullion*, (9) the area of *Crossdoney and Cavan*, (10) the *Mourne Mountains and Coast*, (11) The *older* igneous rocks of *Antrim*, (12) the *Antrim plateau*.

CASE E.—THE NORTH-WEST GRANITE AREA (GWEEBARA).

(Map E; Sec. 26). A broad band of Granite stretches from Malin Head in a south-westerly direction to Gweebara, and comes again to the surface at Glenties. This mass has been the subject of elaborate investigation by Scott and Haughton, who determined that it had the composition of a hornblendic *granitite* with two felspars (2796), microcline and oligoclase (2339), quartz, black and occasionally white mica, hornblende, sphene (2340) and often garnet. The felspars are white and pink (2294), the latter often being large and porphyritic (2806). The authors mentioned above showed that the silica percentage of the rock varies from 72 at Doochary Bridge to 55 at Ardara, on the edge of the mass.

It is frequently penetrated by veins of *pegmatite* (2297, 2308); along certain bands, as at Barnesbeg, it is richly garnetiferous (2302). These bands are on the strike of limestone bands caught up in the granite and highly metamorphosed by it, crystalline calcite, garnets, and other minerals being developed (*v.* page 57). This gave rise to the idea that the granite had absorbed the material of the limestone and acquired a different composition in consequence. Portions of the granite are beautifully foliated, near Glen (2296, 2299), and elsewhere (2291), where the rock is a *biotite gneiss*, often containing rounded crystals of felspar (2299), or else has a granulitic aspect. It has been thought that there was a perfect transition from the surrounding schists through the gneiss into massive granite, a passage which was supposed to indicate that the granite represented the last and highest stage in the metamorphism of the sediments. The reverse is probably the truth, the granite where acted on by great earth-movements, either during or after consolidation, has itself become foliated. Many beautiful varieties of this rock and of the granitite of Barnesmore have been quarried for polishing. *Felsites* (2311), coarse *diorites* (2312, 3),

lamprophyres (2805), massive *amphibolites* (2315), and *epidiorites* (2318) are common intrusive types in the granite and the bordering schists, and *augite-syenite* containing biotite, from Three Tops Mountain, has been described by Dr. Hyland. Porphyritic *olivine-basalts* with quite fresh minerals and possibly of Tertiary age also freely occur (1762).

A remarkable spheroidal granite occurs at Mullaghderg near Dungloe. The main granite is of the normal type, but it is full of flattened spheroids from 1 to 4 inches in diameter which possess both radial and concentric structures. The nucleus of these bodies consists of a granular aggregate of striated felspar (oligoclase), with unstriated orthoclase and some quartz; outside this comes a zone of oligoclase with radially grouped crystals, free from quartz and with occasional flakes of biotite, and over 12 per cent. of iron-ore. This spheroid-bearing rock has been described at length by Dr. Hatch. Polished and unpolished specimens will be found in case XXXIII. Mr. R. H. Scott gives a long list of minerals which have been obtained from the granite and rocks in its neighbourhood, and amongst them schorl (indicolite), beryl (2307), molybdenite and apatite are noteworthy.

Case E.—The Barnesmore Granite Area.

The Barnesmore or Blue Stack area consists of a true *granitite* with black mica only. The felspars are microcline and plagioclase which embed well-formed, small, crystals of orthoclase. The rock is pink in colour, and contains much quartz (1470); it may conceivably be of Tertiary age. It is penetrated by very fresh and probably recent dykes of *pitchstone*, *andesite*, and *dolerite*, which have been described by Professor Sollas. The *pitchstone* (1468, 2335) is black and resinous, sometimes vesicular, and porphyritic; the brownish glassy base contains, according to Professor Sollas, slender needles of pyroxene, minute stellate crystals, and magnetite dust, and in it are embedded porphyritic crystals of sanidine, quartz, and plagioclase. The *augite-andesite* is made up of plagioclase felspar, pale green pyroxene, and magnetite embedded in a glassy vesicular matrix. The *dolerites* are fresh and ophitic with plagioclase felspars set in purplish-brown augite and containing much olivine which in most cases is not in the least decomposed (1464, 1478). Most of these rocks contain porphyritic felspar and they penetrate the granite, schists, and even the Carboniferous rocks of the locality. The great dolerite mass near Donegal (1481), pierces the lower Carboniferous Sandstone. It is a very coarse ophitic *olivine-dolerite* with large masses of augite which enclose felspars and olivines; all the minerals are perfectly fresh. The schists are traversed by dykes of *micaceous felsite* (1474), probably off-shoots from the granite, and *epidiorites*, containing much hornblende (1457), and often converted into micaceous *hornblende-schists* bearing secondary quartz and albite (1458).

Case E.—Raphoe Area.

(Map E.) The schists of Raphoe are pierced by numerous hornblendic *microgranites* (1900) frequently showing porphyritic crystals of orthoclase in a microcrystalline matrix (2817). At Clondermot (2815) there is a dyke of *vogesite* or syenitic lamprophyre, a pink rock with acicular hornblende, showing microscopically well formed crystals of hornblende and orthoclase with a small quantity of interstitial quartz crystallized between them. Numerous *epidiorites* are to be found at St. Johnstown (2321), Convoy (2323), and near Raphoe (2325); they are grey in colour and certainly are highly felspathic and calcareous.

Case E.—Crew and Park.

There are intrusive *felsites* (1573) about Crew in Tyrone, and felsite *breccias* (1576) which seem to indicate contemporaneous volcanic activity; similar felsites are found at Park in Derry. The chief igneous rocks however amongst the schists of Derry are *epidiorites*, often very coarsely crystalline (1484), and still retaining their ophitic structure, although the minerals have been changed. In some the original pyroxene appears to have been diallage, but it and other pyroxenes are now generally converted into actinolite or fibrous amphibole in aggregates.

Case XXXII.—Slieve Gallion.

A plutonic complex containing several interesting rock types occurs in Tyrone, about Slieve Gallion and Kildress. The prominent types are coarse *granites* more or less foliated, and passing into *quartz-diorites*. Both types of rocks frequently contain blue quartz (2820, 2337) together with abundant hornblende, and some mica, chiefly biotite (2337); as usual there are also intrusive dykes of *epidiorite* passing into *hornblende-schist*. At Athenree, and Termonmaquirk near it, there is a very beautiful *gabbro* (1763) exhibiting many of the variations shown in such areas as the Lizard and the Ayrshire Coast where gabbros abound. The pyroxene is present as large, flat crystals of diallage with small metallic-looking plates deposited along its cleavage planes so that it has a glittering bronzy lustre in hand specimens. This mineral varies much in size, some crystals being $\frac{1}{4}$-inch long (3481), while those in other specimens may be 1 or 2 inches. When this great size is attained the diallage makes up the bulk of the rock (3480, 736), as it does in the diallage rock from Lendalfoot in Ayrshire. A plagioclase felspar is usually present, sometimes set ophitically in the diallage, and the last mineral is frequently altered into a mass of fibrous actinolite. A fresh ophitic *olivine-dolerite* is to be found at Gortacloghan (1764).

Case E.—Omagh, etc.

A miscellaneous group is next placed together, because the rocks, for the most part, are interbedded with, or intrusive into, the Old Red Sandstone and Carboniferous rocks of central Ulster. First come the *melaphyres* or altered *olivine-basalts* about Omagh and Recarson—intrusive into the Old Red Sandstone and older rocks. These are purple rocks with no visible porphyritic ingredients except shining opaque crystals, with a bronzy lustre and colour, looking at first like specular iron but in reality referable to a mineral recently described in America as iddingsite. These are clearly pseudomorphs after olivine, a mineral in which the rock must have been rich. As they are set in a ground of plagioclase laths with augite, and possibly some olivine, the rocks may be classed as *olivine-basalts* (2344). About Cappagh, south of Pomeroy, there is found a group of altered *hypersthene-andesites* or *porphyrites*, red or purple rocks (2345), with a very marked flow-structure (2346), almost certainly lavas interbedded with the Old Red Sandstone of that district. Scattered over the Province are many dykes of perfectly fresh *basalt* and *dolerite*, like many already described as certainly post-Carboniferous and probably Tertiary in age. They are mostly ophitic, with plagioclase felspar laths embedded in augite, and with porphyritic crystals of olivine, often quite fresh and unaltered. A zeolite, possibly analcime (1347 from Armagh) occurs as the ultimate product of consolidation or else as a secondary product deposited in place of or between the felspars. The *dolerite* at Lisnaskea contains very beautiful augites colourless internally but deepening to an intense purple brown or even black tint at their planes of contact with the felspars (1419). The great sill (the "Whin Sill" of Ireland) intrusive into the Yoredale rocks of Fermanagh, north of Lough Melvin, is a porphyritic *dolerite*, rich in olivine, but it appears to have been folded, subsequently to its injection, together with the Carboniferous rocks which contain it (1505). If so it can hardly be of Tertiary age; but any more certain evidence than this is wanting.

Case E.—Coast of Down.

The contorted Lower Silurian rocks of County Down contain a number of igneous rocks which, like the sediments, connect this area with the Southern Uplands of Scotland. The chief of these are *lamprophyres* or *mica-traps* belonging to the group of *minettes* and *kersantites*. The usual mica is brown, probably biotite, but it is often bleached and zoned, the interior being lighter in colour than the exterior; occasionally the interior is darker than the exterior, and where that is the case there is generally a black margin to the crystal (2354). The hornblende, which is generally present, is also usually zoned. The matrix of the rocks consists of an aggregate of small, stumpy, usually well formed, crystals of

felspar, but they are often so much decomposed that it is impossible to say whether orthoclase or plagioclase predominates, while at times the two constituents are present in equal quantities. The rocks are in thin dykes, often much twisted and altered, and are usually to be seen on the sea coast; a few, however, have been traced inland. A rock, occurring some miles N.W. of Downpatrick (2356), may be called *hornblendic minette*, those three miles N.W. of the same place (1906) and on the shore at Ballywalter (1903) are *kersantites*, at times augitic, while that from Dillon, S.E. of Downpatrick (2849), is a *camptonite*, and that from four miles W. of Killyleagh (Crossgar? 2354) can only be spoken of as a *mica-trap*.

Case E.—The Newry Granite.

The great mass of granite, extending from Slieve Croob to Newry and on to Slieve Gullion and Forkill, next claims attention. It is a grey *granitite* without muscovite but with quartz, two felspars, black mica, and greenish hornblende (2357, 8). Much plagioclase felspar, probably oligoclase, is present, and this sometimes increases in quantity so much that, though normally a *potash-granite*, the mass locally becomes a *soda-granite*. Sphene and apatite are abundant, and the mica is so much altered to chlorite as to look green in a hand specimen. The rock is quarried for building and ornamental purposes at Goraghwood and Bessbrook (*v.* case XXXIII.) This great granite mass is intrusive into Lower Silurian rocks which are much metamorphosed along the junction plane. Remarkable rocks, which are said to graduate into the granite, have been collected from Slieve Garran (2363, 4); they are not improbably enclosures, either of the nature of segregations or else brought up from below by the molten granite. They are dense black rocks showing, when fresh, biotite, diallage and apatite in great quantity, augite, and both green and brown compact hornblende, often inter-grown together (2364). The diallage, however, gradually passes at its edges into actinolite, and one specimen (2363) retains hardly any diallage at all, it having been replaced by fibrous actinolite.

Parallel with the granite boundary or radiating out from it into the surrounding rocks, or even at times penetrating the granite itself, are dykes which have been mapped as elvanite, and which, judging from Professor Hull's description, vary from *microgranites* to *quartz-porphyries*. Their matrix is microcrystalline or cryptocrystalline, and they contain crystals of orthoclase, oligoclase, mica, quartz, amphibole, and apatite.

Close-grained *basalt* dykes penetrate the granite (2362), and one, of the glassy variety called *tachylite*, is found at Tullynasoo Mountain in Slieve-na-largy, near Castlewellan (2853). It was described by Mr Rutley as a glass, coloured brown by the minute dust which it contained, embedding crystals of magnetite, clouded dark bodies possibly made of magnetite dust, and spherical bodies which

have some of the characters of magnetite. The specimen in the Survey Collection shows, in addition, skeleton-octahedra of magnetite, like those seen in slags, with tiny plagioclase crystals, often mere skeletons made of microlites, and radiating tufts of similar microlites. The analysis of the rock by Professor Haughton gave 55 per cent. of silica and the usual composition of a basaltic glass. A *pitchstone*, with a remarkable platy structure, occurs in the town of Newry (3330). It is a glass, coloured brown by tiny star-like groups of microlites and containing porphyritic crystals of quartz and orthoclase. The chief rock in Slieve Gullion is a hornblendic *microgranite* (1904).

Case II.—Crossdoney and Cavan.

The granite mass of Crossdoney, near Cavan, corresponds with that of Newry in geological position and in many of its characters (1557). It is a *granitite*, sometimes augitic, passing towards the quartz-diorites, white or grey in colour, non-porphyritic, and contains about equal quantities of orthoclase and plagioclase felspar. Under the microscope the felspars, mica, hornblende, and augite, when present, are all found to be idiomorphic and embedded in interstitial quartz in the coarse varieties (1568), in a microcrystalline matrix in the compacter varieties (1555). Sphene and apatite are usually present. The augite is light green and edged with secondary hornblende, while in compact varieties the small micas aggregate round the augite crystals (1556). The mica is biotite of a deep brown colour, and it is frequently intergrown with the hornblende (1563). The rock is devoid of foliation, passes at its edges into fine-grained *microgranite* (1561) rich in biotite, and even into *felsite*, and while itself pierced by microgranite veins at its edges, it includes patches of altered sediments which it has caught up and converted into hornblendic and micaceous *hornfels*. It has exerted great influence on the sediments through which it has been intruded, and its contact phenomena have been dealt with on page 60.

Case E.—The Mourne Mountains.

(Sec. 1.) The granite of the Mourne Mountains is certainly much more recent than the two last described. It is a *granitite* with quartz often smoky in tint (2366), two felspars, orthoclase and albite, and green mica. The order of consolidation of these minerals is not that usual for granites, for, instead of crystallizing last and enclosing the other constituents, the quartz has crystallized first, taken its own crystalline form, and become embedded in the other minerals (2367). This is especially the case on the margin of the mass. This rock is famous for its geodes, which are hollow cavities or cracks lined and filled with the essential and adventitious minerals of the granite; thus quartz, albite, and orthoclase occur in some specimens (1905), beautiful crystals of beryl and

topaz in others, and crystals of chrysoberyl, fluor, peridot, and gadolinite have been found. It is not usually porphyritic, but this aspect is sometimes seen (2371), when the rock would be a beautiful ornamental stone. The very characteristic scenery of the granite area is illustrated by Mr. Welch's beautiful photographs (P. 93, 94, 95). The age of the granite is certainly later than the Carboniferous Period and it may possibly be Tertiary. It presents characters which link it with the Arran granites, and it is known to truncate certain basaltic dykes which are of Tertiary type, and probably belong to the lower set of lava sheets, although it is itself pierced by others of a similar type, probably belonging to the upper set; this would suggest that its age is the same as that of the *rhyolites* to be shortly described.

The coast-line to the east of the Mourne Mountains shows a great variety of igneous rocks. Micaceous *quartz-porphyries* (2855, 6), *felsites* (2859) which are hardly to be distinguished from the rhyolites to be presently described as occurring further north, *andesites*, *basalts* (2857, 2375, 6), and *dolerites*. Many dykes are composite, being filled in with two or more types of rocks, such as rhyolite and andesite, or felsite and basalt (2857). Professor Cole has described an instance where the intrusion of an acid rock (*eurite*) has caused the melting and absorption of some of the constituents of a previously intruded intermediate rock (*andesite*).

Amongst the basic dykes, Patrickson and Portlock discovered examples with *variolitic* structure near Annalong, and these have been re-discovered and described by Professor Cole (1750). This type of rock is generally green, with purple, spherical bodies, or varioles consisting of radiating crystals, scattered through it. This structure appears to be visible only at the edges and probably at the top of the dykes; such dykes are likely to be of very recent date. A great dyke at Rostrevor is much worked for paving-setts; it is an uralitic *diabase* or *epidiorite* containing plagioclase, augite, uralite, viridite, and magnetite (1765). Professor von Lasaulx termed the rock *eucrite*.

Case F.—The Older Igneous Rocks of Antrim.

(Map F; Sec. 2.)—A beautiful diorite of the type called *camptonite* by Rosenbusch occurs at Rue Bane Point, in Antrim, amongst the gneisses and schists. It contains crystalline hornblende and biotite in a decomposed felspathic base, which now includes much calcite and minute needles of hornblende (1896, 2825). *Epidiorites* also occur here (2347). A mass of *quartz-felsite* or *quartz-porphyry* (2836, 2351, 2) occurs to the west of Cushendall, and has provided by denudation a large proportion of the pebbles of the conglomerates at the base of the Old Red Sandstone of that locality (2834). It is a porphyritic rock, red, white, or black in colour, with abundant crystals of porphyritic orthoclase and some plagioclase, brown mica and quartz, in a close-grained ground-

mass, which is a felt of minute felspar needles. In a boss N.W. of Cushendun, and in dykes on the shore, there occurs a bright red porphyritic, *microgranite* (2827, 2830). The phenocrysts consist of orthoclase, oligoclase, and quartz, set in a microcrystalline matrix. The porphyritic orthoclase crystals are beautifully zoned and often very large; they contain, ophitically, numerous small, well-terminated crystals of oligoclase, which are usually arranged parallel to the outlines of the containing crystal. Biotite, more or less altered to chlorite, is a tolerably abundant constituent in some types, and it is sometimes present inside the large orthoclase phenocrysts.

Case F.—The Volcanic Plateau of Antrim.

(Map F; Sec. 12.)—In this area the first rocks to claim attention are the necks, bosses, and dykes, the feeders from which vast floods of basaltic lava proceeded. Amongst the necks may be mentioned Slemish (2402), Tieveragh Hill (2396; P. 74), Scawt Hill (2403, 4, 5), and Carnmoney Hill (2418, 9, 2420; P. 71). The dykes penetrate all the older rocks of the district, Old Red Sandstone (2396), Lower Carboniferous rocks (the Great Gaw dyke, 2386), New Red Sandstone (2425, the Carrickfergus dyke), (P. 58, 60, 78, 89, 90), (Sec. 1 and 2), the Lias (2860) at Portrush, which is baked to a porcellanite without, however, destroying the fossils which it contains (*v.* page 60), the Chalk (2395, 2401), (D 28, 44; P. 59), and the Sheets of Basalt themselves (2388), (P. 77). Most of these dykes are the ordinary type of *ophitic olivine-dolerite.* The olivine has consolidated first in irregular grains, sometimes presenting a rude approximation to the crystalline form; then the iron ores, followed by the plagioclase felspars; lastly, the augite, in great ophitic plates, enclosing the previously formed constituents, especially the felspars. This order is not, however, always maintained, and is sometimes subject to the most remarkable variations. Thus the augite and felspar, and in one case even the olivine and felspar are intergrown together like the felspar and quartz in micropegmatite; while in two cases I have detected the olivine ophitically enclosing felspar crystals, proving that the felspar must have crystallized before the olivine in these instances. A very coarse-grained *dolerite* (or gabbro) occurs at Portrush, the augite being in crystals an inch long. The felspar is, however, mostly replaced by a zeolite (2860, 1). In some dolerites from here the outer portions of the olivine crystals are deep brown in colour (2441). At Fair Head, too, there are coarse dolerites, with beautiful augite crystals, occurring in dykes, laccolites (P. 59), or sills, intrusive amongst the basalt lavas or the Carboniferous rocks below (2389, &c.) In this rock Prof. Judd has described a peculiar feature which he calls glomero-porphyritic structure; the porphyritic minerals are aggregates of anorthite and olivine, set in an ophitic matrix.

A beautiful porphyritic basalt, with bright glassy plagioclase crystals and small olivines, forms a dyke in the rhyolite of Carnearney Hill (2410).

The basaltic lava flows are divided into two main sets, an upper and a lower one, with beds of ash, lithomarge, ochre, &c., between them, and indications, by denudation and deposition, of the lapse of very considerable time between them. There is no lithological distinction between the two groups except that on the whole the Upper are slightly finer in grain and more amygdaloidal than the Lower. The rocks are mostly true *basalts*, sometimes with porphyritic felspar crystals, but more usually quite compact. They are crystalline in microscopic sections showing a felt of long plagioclase crystals set amongst grains of augite which are usually colourless, but sometimes become brown at the edges, especially where bordered by iron ores. The only porphyritic constituent in the compact rocks is olivine (2868); occasionally there is a second generation of smaller olivines in the matrix (2441). Instead of being granular the base is sometimes ophitic on a small scale (2435) and at times the ophitic structure is so large that it is difficult to believe the rock is not an intrusive sheet (2429). Owing to the difficulty of separating intrusive sills from true lava flows where the two have a similar composition and appearance it is quite possible they may have occasionally been confused in the mapping. In the field these rocks are frequently columnar (3475) and columns will be found on the floor of the Survey room and also in a group in the adjoining room (E 4), (D 31, 52, 53, 56; P. 43, 44, 64, 67, 72). Spheroidal structure is also very common (3472, 4), (D 18). The rock is frequently amygdaloidal (2436, 2442, 4, 5) the vesicles being filled with many minerals such as calcite, chalcedony, mesotype, scolecite, natrolite, galactite, stilbite, brewsterite, and a curious substance called hullite.

Interbedded with the basalts and especially between the upper and lower groups are numerous **ash beds** (2450, 2870), which pass laterally into iron-ores, ochres, boles, gravels, and bauxites (*v.* page 68). Considerable masses of agglomerate occur locally and are supposed to indicate vents of eruption, as at Carrick-a-raidlie (2447, 9).

At Templepatrick quarry there is a section which appears to prove that the **rhyolite** of that locality is intrusive into the lower group of basalts. Now as it is certain that there are fragments of *rhyolite* in a gravel which occurs between the lower and upper basalt groups, the age of the rhyolite in this locality seems to be definitely ascertained; it is later than the older basalts into which it is intrusive, and earlier than the upper basalts which rest upon fragments denuded from it. Thus the rhyolite indicates that a considerable lapse of time may have occurred between the deposition of the Lower and Upper Basalts, to allow of denudation penetrating through the cover of basalt into which the rhyolite was intruded before actually reaching that rock itself. This

rhyolite is found at many localities but chiefly at Ballymena (2873), Tardree (2455) and Sandy Braes (2458), at Templepatrick (2463), and near Moira (386) in Down. It is possible that, although intrusive at Templepatrick, it may have flowed out at the surface as lava at some of the other localities. This supposition is suggested by the flow and perlitic structures, the glassy aspect, and other characters presented by the rhyolite at Sandy Braes and other localities. These characteristics can all be matched in the recent rhyolites of Hungary. The rock is acid in composition and contains 76 per cent. of silica. This shows itself in porphyritic crystals of quartz and sanidine which occur side by side with those of plagioclase felspar, almost certainly, albite there being very little lime on the rock. Ferromagnesian consituents are rare, but biotite and hornblende have been noticed, together with magnetite, epidote, apatite, zircon, and sphene. Von Lasaulx detected tridymite in plenty as minute scaly aggregates. These minerals are embedded sometimes in a pure brown glass when the rock is a porphyritic *obsidian* or *pitchstone*, but more usually the glass is crowded with minute curved trichites or crystallites. The rocks are brown or greenish in colour and show their porphyritic quartz and felspar crystals clearly to the unaided eye (2874, 7). At Sandy Braes, where the characters just mentioned are best seen, the rock is often beautifully perlitic, a structure due to the shrinkage of the rock as it cooled, and which has affected not only the glassy base of the rock but the enclosed quartz crystals. The grey "trachytic" varieties more common at Tardree and Templepatrick (2464) are quite similar in their porphyritic constituents, but these are embedded in a matrix not now if ever glassy, but made of a felt of orthoclase microliths associated with quartz and probably tridymite (2882). Sometimes the matrix is cryptocrystalline and the actual character of its components cannot be ascertained (2881). Occasionally the cores of the porphyritic crystals are striated felspar completed by the addition of zones of orthoclase (2463). When the rock has undergone a great deal of decomposition it becomes warm brown or red in tint (2459, 2460), and opal is not infrequently present in these decomposed varieties (2875). The flow structures are often very beautiful (2880) and are due to bands of different colour, hardness, or resisting power, to streaks of microlites in the glass, to the alternation of glassy and stony bands, or to bands with microlites alternating with those possessed of cryptocrystalline structure.

Of the **upper lava-sheets** but little remains to be said; they are mostly *basalts*, compact, and with a minute crystalline structure (3473, 2466). Some, however, are coarser and show ophitic relations in their principal minerals (2467, 9). These rocks rest on ashes and in hollows denuded in the older set of lavas.

4.—MUNSTER.

1. GENERAL ACCOUNT OF THE ROCKS.

The rocks of this Province are traversed by a series of folds which trend from a point a little north of east to one a little south of west. These folds bring Silurian rocks to the surface at the north-east, south-east, and west of the Province, but over the rest of the area only Devonian (or Old Red Sandstone) and Carboniferous Rocks are displayed in alternating ridges and troughs, crossed and truncated by a second set of slighter folds trending north and south. The mountain tracts usually occur on the anticlinal lines, where the Devonian and Silurian rocks make their appearance, and particularly where—as about Killarney—these are associated with igneous rocks. The Coal Measures are to be found in Limerick and Tipperary, Lower Carboniferous rocks only being left undenuded on the southern synclines, amongst which, and the associated Devonian rocks, some mineral veins occur.

The succession of rocks in Munster may be thus stated, in descending order :—

Systems.	Series.	Igneous Rocks.
6. Pleistocene, . . .	—	
?	Pipe Clays, &c.	
4. Carboniferous, . .	Coal Measures, ... Millstone Grit, ... Yoredale Series, ... Carboniferous Limestone, . . Carboniferous Slate, &c., . .	Intrusive and Interbedded Rocks.
3. Old Red Sandstone, .	Upper Old Red Sandstone, . . Lower Old Red Sandstone and Dingle Beds.	Intrusive and Interbedded Rocks.
2. Upper Silurian, . .	—	Intrusive and Interbedded Rocks.
1. Lower Silurian, . .	—	Intrusive and Interbedded Rocks.

CASE XXVII.—THE SILURIAN SYSTEM.

The rocks of this System occur inside a series of inliers surrounded by Old Red Sandstone, dotted about in the wide area of Carboniferous strata of the North-eastern and Central parts of the Province, in the area of Clogher on the west, and of Waterford to the east. The following areas demand description :—(1) *Lough*

Graney; (2) *Slieve Bernagh, the Silvermine Mountains, Slieve-Felim*, and *the Devil's Bit*; (3) *Slieve Galty*; (4) *Slievenaman*; (5) *The Comeragh Mountains*; (6) *Clogher Head* and *Dingle*.

Everywhere the rocks are green, grey, or blue *grits, slates*, and *flags*, with beds of *sandstone*, rare *limestones*, and black *slates*. The slates are especially quarried and utilized in Clare, Cork, Kerry, and Tipperary. At **Lough Graney** the beds answer this description (1746, 7); they are imperfectly cleaved, and, about Scalpnagown, contain beds of volcanic ash and breccia, and masses of felsite, andesite, and amygdaloidal diabase, some of which are intrusive, but others are undoubtedly lavas of contemporaneous date (*v.* page 90). No fossils have hitherto been found in these rocks, and their exact age is unknown. In the **Slieve Bernagh** range occur compact green *grits* (1676), purple (1682) and green *slates* (1666, 1679), quartzo-felspathic *sandstones* (1680), with olive and red clay rocks; fossils are fairly abundant. Workable slates are quarried at Killaloe and elsewhere in Slieve Bernagh. From Sixmilebridge, *Cœnograptus* and *Dicellograptus* have been obtained in beds which must be of Llandeilo age, while the presence of Llandovery, and perhaps higher, rocks in the neighbourhood, is indicated by the presence of *Cyrtograptus, Monograptus priodon, Petraia, Cardiola interrupta, Euomphalus funatus, Atrypa marginalis*, and other forms at many localities in the **Silvermine** and **Slieve Felim** Mountains. Copper mines have been worked in these beds at Lackamore, and graphitic anthracite occurs in the Silurian beds of Upperchurch. The exact order of succession being unknown, it is impossible to give even an approximate estimate of the thickness of rock. **Slieve Galty** is made up of hard green or grey quartzose *grit* (1699) and dark olive and black, sandy, *shales* (1701, 1702), from which no fossils are recorded.

Jukes suggested that the western group of dull *green* and *purple rocks* in **Slievenaman** might possibly be Cambrian, while the blue and grey *slates* and *grits*, with dykes of diabase and felsite and beds of volcanic ash, to the east, were probably Lower Silurian; but the fossils since collected from the western group prove that it also is Lower Silurian. In **Waterford** (Sec. 50) pale grey or purplish *shales* with thin *grits* (916), narrow bands of *limestone*, and thin beds of black *shale* (848, 849), in which numerous graptolites are found, occur at Tramore and at Gibbet Hill. These include *Leptograptus flaccidus,? Dicellograptus sextans, Diplograptus mucronatus, Climacograptus (bicornis ?)*, and *Dicranograptus ramosus*, which indicate the Llandeilo age of the rocks. These beds compare with those of Sixmilebridge on the one hand, and of Ballymoney, near Gorey, on the other. Judging by the lists of fossils given by Mr. Baily, it would appear that a *limestone*, approximately equivalent to that of Llandeilo, is present in the series, and that the liver-coloured *conglomerates* and *shales* interstratified with volcanic rocks (*v.* p. 112), and associated with pale grey calcareous *grits* and flaggy impure *limestone*, con-

taining Trilobites, are of Bala age; there would appear, however, to be no Upper Silurian rocks in the area. This district contains an enormous amount of intrusive rock, which will be referred to on page 89, and associated with the igneous rocks are the veins of copper ore worked at the Knockmahon mines.

The remarkable group of Silurian rocks in the **Dingle** promontory has been broken up by Jukes and Du Noyer into the following divisions, given in descending order :—

3. The Croaghmarhin Beds = Ludlow Series.
2. The Ferriter's Cove Beds = Wenlock Series.
1. The Anascaul Beds = Llandovery?

1. *The Anascaul Slates* are black and glossy (746), occasionally red or green, with *flags* (1276) and a few beds of *limestone* (743, 744). It has been suggested that the latter may be of Bala age, but the bulk of the fossils are such as are obtained from Llandovery rocks. Their relationships with the rocks of the west of the promontory are obscured by old Red Sandstone, but it is not unlikely that the barren *sandstones* and *flagstones* with bright red *shales*, dipping under the Series next to be described, and called the Smerwick beds, may be their equivalent in point of age. They appear to be 2,000 feet thick.

2. *The Ferriters Cove Beds* begin with *conglomerates*, followed by green sandy *shales*, interstratified with beds of felspathic ash and agglomerate, and several lavas consisting chiefly of nodular felsite (*v.* p. 91), succeeded by red *sandstone* and *slate*. They are full of typical Wenlock fossils (*v.* page 112), including Brachiopods and Trilobites, and are 2,500 feet thick.

3. *The Croaghmarhin Beds* are *flags* (796) and *grits*, occasionally with tracks of molluscs or annelides (1275); they are 1,000 feet thick, and contain fossils of Ludlow and Aymestry affinities. These rocks are much folded, and even in places inverted.

CASES XXVII AND XXVIII.—THE OLD RED SANDSTONE.

This is the most important rock System in Munster, and it has been mapped under the head of three principal divisions—Dingle Beds, Lower Old Red Sandstone, and Upper Old Red Sandstone. For purposes of description here it will be best to use only two divisions; a Lower, including the Dingle Beds, for those rocks which are conformable to the Upper Silurian when it is present, but generally unconformable to the Lower Silurian; and an Upper (the Yellow Sandstone Series) which passes up conformably into the Carboniferous rocks, but usually rests on the Lower Old Red Sandstone, Dingle Beds, or anything older, with extreme unconformity.

The areas into which the description can conveniently be divided are the following :—(1) *Lough Graney*; (2) *Slieve Bernagh*: (3) *Slieve Felim and the Devil's Bit*; (4) *Knockfeerina*; (5) *Slieve*

Galty; (6) *Knockmealdown Mountains*; (7) *Dingle*; (8) *Iveragh and Killarney*; (9) *Glengarriff*; (10) *South and West Cork*; (11) *East Cork and Waterford.*

The same broad characters are recognisable throughout the whole range of these rocks. Deep red, liver-coloured, and chocolate, *sandstones*, *conglomerates* chiefly made of quartz pebbles, green and grey *greywacke-grits* (Dingle type), green, grey, and blue *slates*, and occasional seams of very impure sandy *limestone*, called *cornstones*, which are sometimes conglomeratic. Organic remains are rare, a few Fish and Plants being all hitherto discovered. The rocks have almost certainly been formed in great inland lakes.

The upper division is made up of yellow and reddish, rusty, *sandstones*, with plant remains and occasional freshwater shells.

About **L. Graney** 800–1,100 feet of Upper Old Red Sandstone unconformable to the Silurian, and containing fossil Plants, occur. There is a soft red *sandstone* or *breccia*, often a *cornstone*, at the base, filling up the denuded hollows in the Silurian rocks, and on this come red and yellow *sandstones* (1660, 3), *shales*, *flags*, *cornstones*, and *conglomerates* of increasing importance towards the North (1662, 5, 1749). On **Slieve Bernagh** there are yellow and red quartzose *grits* (1668) and *sandstone* (1685), with *shales* and *flags* 1,300 feet thick, but thinning to 450 feet in the South-west. At **Slieve Felim** the rocks are unusually calcareous, and consist of *cornstones* with yellow (1017), purple (1016), and white (1014), *sandstones*; the Series thickens from 800 feet in the North to 1,500 feet in the South. The Upper division alone is present in these areas and at **Knockfeerina** (map G), where it is pierced by "necks" of volcanic rock and associated with ash beds (*v.* page 95).

At **Slieve Galty** the Lower division begins to come in and is from 3,000 to 4,000 feet thick, made up of thick beds of red *conglomerate*, covered by red and liver-coloured *sandstone*, the unconformability of which to the Silurian rocks is shown by their containing pebbles derived from them. The Upper division contains plant remains, is 800–1,000 feet thick, and consists of yellow (1705, 1035) and brown-banded *sandstones* (1707). The Lower division in the **Knockmealdown Mountains** has much the same character, but is less conglomeratic, and 4,000 to 5,000 feet of rock are seen without the base being reached; where the base is seen to the east the division seems to be thinner; the top 1,000 feet, containing yellow or white *sandstones* and *conglomerates* (759, 1036), are mapped as the Upper Old Red Sandstone.

In the **Dingle Promontory** the lower beds of the Old Red Sandstone (Dingle beds) rest with apparent conformity on the Croaghmarhin (Ludlow) rocks, although there are some facts difficult to account for on this theory; they attain a thickness of at least 10,000 feet. Amongst the green and purple grits (662, 5) with *slates* and *cornstones* (756), all unfossiliferous, occurs a *conglomerate*, that of Parkmore, containing pebbles of grit, hornstone, slate, ash, and limestone, some of the fragments bearing Llandovery

fossils, which have apparently been derived from the denudation of Silurian rocks. The Upper Old Red Rocks rest with marked unconformity upon everything below them, and in the Caherconree Mountains an old cliff of Silurian rock, 500 feet high, is apparently buried up by the accumulation of the Upper Old Red Sandstone. The rocks are of the usual character, but they contain a great band of *conglomerate* called the "*Inch conglomerate*" (748, 9, 750, 1; 661, 883, 1277), made up of fragments of granite, gneiss, and mica-schist, none of which have yet been anywhere identified *in situ*; this conglomerate varies from 400 feet to 6 feet thick in the Dingle Promontory, where the whole Upper division of the rocks is 3,000 or 4,000 feet thick.

The great mass, extending from the **Iveragh Promontory to Killarney** (Map G), has been mapped into three divisions, the Glengarriff Grits, the Lower, and the Upper Old Red Sandstone; as, however, the two first divisions pass into one another laterally the distinction is merely a lithological one. The lowest rocks contain green (1010, 1011), red (663), and purple (1007, 8), *grits*, highly micaceous and *conglomeratic* (1002), with purple (1003, 6) and green (754) *slates*, which take on different colours under the action of the sea and the weather; the upper division is thin, and of the usual brown and yellow colours. A set of igneous rocks, interbedded and intrusive felsites and ashes, occurs on Valentia Island and in the picturesque mountains about Lough Guitane, near Killarney (*v.* pp. 91 and 92), while west of that place the Old Red Sandstones rise into the grand heights of the Reeks, the loftiest mountains in Ireland. A number of Du Noyer's drawings illustrate the mountains formed of Old Red Sandstone in Kerry (D 3, 5, 6, 10, 14, 16), and three others (8, 9, 15) give views of sections or mountains where the volcanic group can be seen. The total thickness of Old Red Rocks seems to be not less than 13,000 feet. In the **Glengarriff Region** both Upper and Lower divisions are present, and there are igneous rocks (*v.* p. 91) in the extreme west and on Dursey Island, while sedimentary rocks of the usual types (880, 1037, 667, 760, 1019, 1020) occur in the extreme **Western** and **Southern** parts of **Cork**. Between the Upper and Lower divisions in the extreme South, green, copper-bearing, *sandstones* (1278) occur amongst the limestones, and they are traversed by lodes of copper-pyrites, which have been worked with profit at Alihies, near Berehaven. About Bantry there are veins of barytes in the Old Red slates and grits, and on the south coast of Cork the rocks are banded with beds of grey copper ore passing into malachite and azurite. In **East Cork and Waterford** (Map A) the total thickness varies from 5,000 to 9,000 feet, and the whole series appears to be a conformable one. The Upper Beds have not only yielded fossil plants but also the shell *Anodonta Jukesii*, whose nearest living relative is the freshwater mussel. This fossil is of great value in indicating the extreme probability of the view that the Old Red Sandstone was formed in great freshwater lakes. The unconformity between the Old Red Sandstone and the Silurian rocks is well shown in Du Noyer's drawing, D 17.

Cases XXIX.–XXXI.—The Carboniferous System.

The Carboniferous Slate and Coomhola Grit.—In the northern part of the Province this Series is thin, from 150 to 400 feet, and consists of *shales*, *flags*, *sandstones* (678), and hard siliceous *grit* (1670), with a few *limestones* in Clare and Limerick. Further South it assumes the characters of the two lithological types, named by Jukes Carboniferous Slates and Coomhola Grits. These two types graduate into one another laterally, and cannot be regarded as chronological sub-divisions, although grits are, as a rule, more common in the lower part of the Series. The rocks thicken rapidly towards the South as they are brought up in the recurring anticlinals, and become successively 1,500, 3,000, and even 6,000 feet in thickness; indeed, from Crookstown to the Old Head of Kinsale, the slate series thickens from 60 to 6,000 feet in 18 miles. There can be little doubt that as the Carboniferous Limestone occupies less and less space in these anticlines, the beds of grit and sandstone to a large extent replace the lower beds of the limestone of the North, showing that while a deep sea extended in the Carboniferous Limestone Epoch over the north of Munster, its southern shore-line was not far south of Ireland.

The prevailing character of the rocks is as follows:—Olive and black (865) *shales* and *slates* (799, 1024), often fossiliferous, containing marine shells, and sometimes showing radial groups of wavellite crystals (793), with grey (882, 666) and blue siliceous *grits* (1022, 3, 5), often used for building purposes. The rocks are much disturbed by frequent folding and faulting, caused by the great earth-movements which, at the end of the Carboniferous Period, ridged up a mountain range extending from the West of Ireland through Devonshire, under London and through Belgium to the Ardennes, a ridge now mostly covered up and concealed by sediments deposited in later times. These rocks are apparently pierced by a mass of gabbro at Mishells in Cork, while on Bear Island and the adjoining coast they are penetrated by a curious set of felsitic, andesitic, and basaltic intrusions, and by necks and masses of hornblendic and micaceous tuff (*v.* pp. 90 and 91.)

The Lower Carboniferous Limestone.—In the district of Clare and North Limerick the lowest division of the Limestone Series consists of two members, the Lower, stratified, dark, and argillaceous, followed by beds of thin *limestones* and *shales* with *cherts* (1672), the Upper, grey, and blue massive *limestone* sometimes more or less magnesian. The upper division furnishes the red, purple, and variegated stone quarried for marble in Limerick. The thickness of the lower Stage varies from 1,200 to 1,600 feet, and it becomes very impure and earthy towards the South and West, where veins of iron- and copper-pyrites, hæmatite, blende, and argentiferous galena occur. In the Knockmealdown Mountains a limestone with a very curious concretionary structure is found (1279); near Killarney some bands contain small crystals of quartz (777); while about Cork very beautiful red, pink (1026, 8),

grey (1032), and variegated limestones are quarried for marble. Cherts from these localities are figured in the drawings 7, 20, and 33. In places the bedding of the limestone is very thick or obscure, but, when this is the case, it is cut by prominent joint-planes.

The Middle and Upper Carboniferous Limestones can only very rarely be separated in Munster. One of the most remarkable of the Carboniferous Limestone tracts in Ireland is that situated just south of Galway Bay, in the N.W. corner of Clare, where the rock puts on the aspect under which it is called the Burren Limestone, from the barony of that name situated here. The *limestone*, much used for building in Clare, varies from pale bluish to dark grey in colour, and is split up into beds often as much as 20 feet in thickness. It is traversed by several sets of joints, the chief of which are two sets which run about N.E. by N. and S.W. by W. Denudation takes place along these joint planes and the bedding planes, and brings about the formation of terraced hills which would be horizontal table-lands but that the limestone dips gently to the south; the weather, penetrating deeply into the rock along the joint planes, forms deep grooves many feet in depth, which often either swallow up rivers and streams or give egress to them at the surface. The hills are in places over a thousand feet in height, and, running to the sea, they weather away in the grand Cliffs of Moher, which rise vertically to a height of 668 feet above the sea. 1,500 feet or more of this limestone are to be seen. Features like those just described are also seen in the Aran Islands which are built of the same limestones.

On the south side of Slieve Bernagh, at the Silvermine Mountains, the limestones are brecciated (1678) and filled with veins of barytes (1675), argentiferous galena, blende, ores of iron and copper, associated together with other minerals in a siliceous breccia. Some of the galena here contains from 20 to 55 ounces of silver to a ton of lead, the ore yielding 66 per cent. of lead. In the basin south-east of Limerick (map G) a set of lavas and ashes, chiefly of porphyrite and andesite, occurs between the Lower and Upper divisions of the Limestone, while a second set of volcanic rocks, chiefly basalts, limburgites, and ashes, is found between the Upper Limestones and the succeeding Yoredale shales. The Higher Limestones do not occur further south than Killarney, where the entire thickness of all divisions of the Limestone is from 1,500 to 2,000 feet, and the highest rocks seen are dark grey and granular (775), cherty and often magnesian in composition (1722, 4, 6, 778), or else, but more rarely, light and sub-crystalline (1736, 1744).

The Yoredale Series.—This Series is chiefly found in Clare, Limerick, and Kerry, and consists of black fissile (867), or olive *shales* (920), followed by alternating *grits*, *flags*, and *shales*, with thin seams of *coal* and calcareous fossiliferous beds containing *Posidonomya*. It varies from 800 to nearly 3,000 feet in thickness.

Specimens of greenish (1734) and dark grey *sandstone* (1689) and siliceous *grits* will be found in the cases.

The Millstone Grit or so-called "Flagstone Series," follows, and is everywhere made up of hard *grits* (782) and flags (1693, 1729), or white micaceous *sandstone* (1691) occasionally showing tracks of mollusca (783, 4) and plant remains (1695). The rock appears to graduate up into the Coal Measures, the line being drawn below the oldest bed of coal.

The Coal Measures.—In the Kerry, Limerick, and Cork coal-fields the Coal Measures consist of alternations of *grits*, *sandstones* (786,7), *flags*, and *shales* (789) sometimes used for brickmaking, with beds of *coal*, *fireclay*, and *clunch*, in the upper part of the series. The coal-seams are as much as 7 feet in thickness, but part of this is made up of layers of shale interbedded with the pure coal. The aggregate thickness of coal is from 6 feet 6 inches to 18 feet, separated into six seams by 700 feet of sandstones and shales and covered by a considerable but unknown thickness of upper beds, in which coal is not certainly known to occur; *clay-ironstone* is also present (794).

The Tipperary coalfield (Sec. 50) belongs geologically to the Leinster field and is similar to it in character. The Lower division contains about 3 feet of coal, in three seams separated by about 800 feet of measures, while the Upper Coal Measures, beginning with the Main Coal of Jarrow, contain five seams, 10 feet in aggregate thickness, separated by about 400 feet of *shale* (1280), *sandy shale* (795), and *sandstone* (1730), which yield the remains of *Calamites* (785) and other fossil plants (781). The coals are *steam-coals* or *anthracites* (*v.* Case XXXIII.)

There are several small basins of Coal Measures in South Cork which rest conformably upon the Lower Carboniferous Slates. They consist of black *shales*, several hundred feet thick, and yield *Posidonomya*, *Goniatites*, *Orthoceras*, and skeletons of fish such as *Cœlacanthus*. These basins occur near Ballinhassig, Kinsale, Bandon, Bantry, and on Widdy Island in Bantry Bay.

Case XXXI.—The Tertiary Group.

Rocks of Unknown Age.

Pipeclays and Lignites.—In the county of Tipperary, both north and south of Caher, interesting deposits of these substances are found. They rest in hollows in the Lower grey Limestone and the patches vary from 100 to 200 feet in diameter, and from 40 to 100 feet deep. They are irregular in form, dip down with the angle of the basin, and seem to line rather than to fill the pockets. The *clay* rests on sand, is white with a pale shade of blue, but varies considerably in purity, and is soft and soapy in texture. A seam of *lignite* was found at a depth of 15 feet in one pocket, and the purest clay was under this. It is noteworthy that swallow holes occur in the limestone near, and it has been suggested byMr. Maw that, while the hollows are due to the solution of lime-

stone by water, the clay is a residual product left when the limestone was removed. Somewhat similar deposits are found in the limestone districts of England and Wales, and for want of better evidence they have been paralleled with the Eocene pipeclays of the Hampshire Basin, and the lower clays of Lough Neagh.

Case XXXI.—Pleistocene System.

The Lower Boulder-Clay.—The hills of the South and South-west of Ireland are smoothed and glaciated to a height of 1,000 feet above the sea, showing that the ice-sheet must have been at least as thick as this. The boulder-clay is thick, characterised by large erratics, some of which must weigh 1,100 or 1,200 tons, like those on Ship Lough, near Dunmanway. Blocks of Galway granite are found in Kerry, Clare, Limerick, and Tipperary. The Clay extends up the flanks of the mountains to a height of 1,500 and even 2,000 feet. Angular and **limestone gravel** sometimes cemented into a solid conglomerate or breccia, **Upper Boulder-Clay, Eskers,** extending to a height of 900 feet above sea level, and a gigantic series of **Local Moraines** in the mountains of Killarney and Waterford (D. 4), occur in this Province. A perched block from the Devil's Punch Bowl is figured by Du Noyer (D. 39). **Shell marl,** containing living species of shells, occurs above the limestone gravel and under the peat bogs, marshes, and gravels. Submerged **Peat bogs** occur in Courtmacsherry Bay and elsewhere, and ancient tree-stumps embedded in shore-shingle combine to give evidence of recent depression of the coast line. The **Caves** near Mitchelstown in Cork are lined with masses of carbonate of lime in the form of *stalactite* and *stalagmite* (792, 895, and pedestal 47).

2. THE IGNEOUS ROCKS OF MUNSTER.

This Province is remarkable for the absence of any considerable masses of plutonic or foliated rocks, such as characterise the Northern and Western Provinces. Indeed, except in Waterford, Limerick, and Kerry, igneous rocks of any sort are decidedly rare. It will be convenient to class what is to be said on the rocks under the following heads:—(1). *The Waterford Area.* (2). *Mishells.* (3). *Lough Graney.* (4). *The Dingle and Clogher Head Area.* (5). *Dursey, Bear Island, and the adjoining mainland.* (6). *The Lough Guitane Area.* (7). *Limerick.*

Case G.—The Waterford Area.

(Map G).—This region may be regarded as the southward continuation of the great mass of igneous rocks associated with the Lower Silurian strata of Leinster, the intrusive and interbedded rocks to the east of the granite. Most of these rocks are intrusive into the Lower Silurian sediments, and their relations are admirably displayed along the coast line from Stradbally to

Great Newtown Head. There are great bosses and dykes filled with intrusive *felsites*, masses of *agglomerate* filling "necks" of the old volcanoes, intrusive sills, lavas which have flowed on the surface of the land or the floor of the sea, and beds of agglomerate tuff, and ash. Most of these rocks are *rhyolitic* in composition (2129, 2132), some show porphyritic quartz (2131), others only porphyritic felspar, while others again are quite compact and horny or only show their quartz and felspar crystals in microscopic slides. The most beautiful examples of banded (2130, 1874) and twisted flow structure are of frequent occurrence. Microscopically, the ground mass of these felsites is of that compact character spoken of as cryptocrystalline, and this is seen to embed crystals of orthoclase and plagioclase felspar with quartz, and mica or hornblende (2140), and sometimes both. These rocks have often been strained and broken or brecciated (2142) by earth-movement, but have not usually undergone so much re-crystallization or re-arrangement of their constituents as those of Leinster. It is highly probable that these felsites, like those described by Dr. Hatch from Wicklow, and those of similar date in N. Wales described by Mr. Harker, may pass from normal *potash-felsites* through every grade of transition to *soda-felsites;* indeed one of Dr. Haughton's analyses shows that the felsite of Bunmahon contains equal quantities of potash and soda. Beautiful spherulitic, nodular, and concretionary, structures frequently occur (2141). The *tuffs* and *ashes* are largely made up of fragments of the felsites (2144), but contain clay galls and limestone fragments as well (2145). Some intrusive masses of *diabase* or altered *dolerite* have been identified in the area, and it is highly probable that this volcanic series will be found, on fuller examination, to contain many different rock types. As a whole, their date doubtless ranges from Lower Silurian to Upper Silurian, while some of the intrusions may be of still later date.

Case G.—Mishells.

Next to this series will be found a specimen (2151) of a coarsely crystalline, apatite-bearing, *ophitic dolerite* which occurs in numerous blocks at Mishells, N. of Bandon in Cork, but which has not yet been unequivocally demonstrated to be *in situ* at that locality; of this, however, there can be no reasonable doubt, and the rock must be intrusive into the Coomhola grits.

Case G.—Lough Graney

An interesting group of igneous rocks is found about Lough Graney in the Lower Silurian strata. Pink and white *rhyolites* (2200), *orthoclase-felsites* (2196), *porphyrites* or altered *andesites* (1745, 1882), with interbedded *tuffs* and *ashes* made of felsite and containing lumps of limestone and vesicular fragments, are interbedded with the Lower Silurian strata. *Diabase* (1654), probably intrusive into the other rocks, also occurs here.

Case G.—Dingle and Clogher Head.

The Igneous rocks at the western extremity of the Dingle promontory are of exceptional interest because they are interbedded with Upper Silurian sediments in which such fossils have been found as to determine their age to be from the Llandovery to the Wenlock Epoch. The rocks are mostly *felsites* (2182), not usually bearing free quartz (3457) except where the rock has been crushed and a new arrangement of minerals has been set up. They are often columnar (2185) and exhibit fine flow structure (3458, 3459, 2181), often of that type known as eutaxitic (3461); most of them are spherulitic (3456), and this structure becomes at times visible to the naked eye and is then called nodular structure. It is well seen in the beautiful polished specimen (3456), and in those which are weathered (2774); sometimes the nodules are hollow (3463). Epidote is a frequent constituent of the felsites and also of the ashes associated with them (2772). There are also *ophitic diabases* which are likely to be intrusive rocks but little later in date than the interbedded igneous rocks, and some very fresh *olivine-dolerites* which may be of much later date (3467). *Felsites* and *dolerites* occur at Beginish Island, between Dunquin and Great Blasket (2776, 7), highly decomposed basic rocks in the Lower Silurian strata of Anascaul (2728), and *felsites* in the "Dingle Beds" at Valentia Island (2753).

Case G.—Dursey Island and Bear Island Area.

At the end of the peninsula which divides Kenmare River from Bantry Bay there are many peculiar types of igneous rocks associated with the "Dingle Beds," Old Red Sandstone, and Lower Carboniferous rocks of Dursey Island, Cod's Head, Blackball Head, and Bear Island. At Cod's Head and Tillick-a-finna on Dursey Island, in dykes through the Old Red Sandstone, occurs an *epidosite*, a rock now almost solely consisting of green epidote (2755, 2759, 2762). The rock is fibrous and of a beautiful green colour, it weathers to a peculiar, brown, carious or spongy, surface, and water-clear felspar with a little quartz are seen to be present in microscopic slides; the rock is probably the result of the decomposition of a *dolerite* or *diabase*. A bed of *ash* occurs at Crow Head (2765), and *basalts* or *dolerites*, sometimes amygdaloidal (2152), are not infrequent.

At Blackball and Whiteball Heads there are intrusions of *felsite*, one of which is augitic; it is very fresh and gives out a musical ring when struck with the hammer (2163); its lustre is waxy, and, as nepheline appears to be present, the rock is probably a *phonolite*; other felsites are dull and decomposed. The most remarkable rocks are clearly fragmental, and yet they sometimes traverse the bedding at right angles, while at other times, although vertical, like the bedding, they contain fragments of both the lower and upper strata, proving that they are subsequent in date to the rocks which contain them. They are *volcanic tuffs*, and

usually contain lumps of felsite and andesite, but fragments of large crystals of muscovite (2159) and rounded crystals of schillerized hornblende, sometimes from one to three inches in diameter (2160, 2767, 8, 9) are of frequent occurrence in them. These rock masses can only be explained by supposing that they have been ejected through the containing strata, after the latter had been tilted to their present angle, for it is impossible to conceive any force which could have injected fragmental material between the bedding planes of strata when they were horizontal or at a low angle. When it is added that these strata are of Lower Carboniferous date, and that the great Hercynian earth-movement which threw them into their present folds and position was of post-Carboniferous or even partly of post-Permian date, the problem of the age of the intrusive rocks becomes a very fascinating one.

Connected with the last set of rocks are the *felsites* (2166) intensely brecciated (2177), the *porphyrites* with porphyritic crystals of felspar, augite, and hornblende, which have undergone an extraordinary alteration into an opaque whitish or greenish substance (2164), and the ophitic *diabases* and *dolerites* (2179), which occur as dykes all along the coast of Bear Island, and may sometimes be demonstrated to extend far inland.

Case G.—Lough Guitane.

(Map G.)—Igneous rocks are associated with the "Dingle Beds" at Lough Guitane, Benaunmore, Stoompa, and Glenflesk, near to Killarney, and in their general lithological character come very near to those previously described from Clogher Head and Dingle. The lavas and intrusive *quartz-felsites* or *rhyolites* do not as a rule contain much free quartz, although Dr. Haughton's analysis shows that they possess 71 per cent. of silica; they generally show porphyritic crystals of felspar, chiefly orthoclase but also plagioclase, and some hornblende (2195). The rocks weather perfectly white (2193), but are greenish grey when fresh (2191), and exhibit beautiful flow structure which is especially well displayed on a weathered surface (2194). Some varieties have dark spots, and others contain cubic crystals whose composition has not yet been determined, but which weather out into rusty brown spots. The rocks are frequently nodular; the nodules vary from less than a pea in size to 5 inches in length, and are sometimes hollow, with crystalline quartz inside them (2779, 2782, 3); at other times the felspar crystals of which the nodule is made radiate out from a centre, and such nodules exhibit the rare phenomenon of flow structure passing through the radial crystals (2780). The finer-grained rocks are often spherulitic, and the quartz and felspar of the spherulites are intergrown like micropegmatite (centric structure). *Ashes* and *tuffs* are associated with the lavas, and these graduate up into the ordinary greywacke grits of the Dingle Beds here. The rhyolite dykes are often columnar in structure (D. 8, 9, 15).

CASE G.—LIMERICK.

(Map G.)—The basin of Carboniferous rocks south-east of the town of Limerick contains a series of igneous rocks which link that area with the Central valley of Scotland and the rocks described by Sir A. Geikie and Dr. Hatch. They consist of two sets of lava-flows accompanied by ash beds, the lower set, between the Lower and Middle Carboniferous Limestone, being on the whole more acid than the upper set which intervenes between the Carboniferous Limestone and the Yoredale Rocks.

The Intrusive Rocks.—In the area occupied by the volcanic rocks themselves, and outside it in the Limestone area, are a number of bosses of intrusive rock which appear to be the vents from which the lavas, at any rate the lower set, were ejected. They are a somewhat anomalous class of rocks. Those which lie furthest from the volcanic basin, as at Oola and Maddyboy are very difficult to name, as although they have a good deal in common with the trachytes they are crystalline throughout. Perhaps the best name for them will be *trachytes* or quartzose porphyrites, or a new name such as *ivernite* might be bestowed on them. They are red, granitic-looking rocks which are made up chiefly of stumpy idiomorphic prisms of felspar which is chiefly orthoclase. Some plagioclase also occurs, and the two felspars are embedded in interstitial quartz, which is sometimes in granules (2201, 2) but usually not (2205, 6, 8, 3469). A trace of hornblende or mica is frequently present and the rocks contain about 65 per cent. of silica. Porphyritic crystals of orthoclase and a few of plagioclase occur in them. The intrusive rocks nearer the basin, in some cases injected into the lava and ash beds themselves, are similar in their porphyritic ingredients, but plagioclase becomes more common both as a phenocryst and in the lath shaped crystals of the ground mass. They contain 60 to 61 per cent. of silica, and their decreasing acidity is further shown by increased calcite, chlorite, and serpentine which evidently replaces augite and possibly in some cases olivine. They seldom show any interstitial quartz, and stand between *trachytes* and *porphyrites* (2214, 5, 9); some are perhaps *bostonites*.

The Older Volcanic Series.—The earliest lava-flows in the northern part of the area are close grained *basalts*, which must once have contained porphyritic olivine. The base of the rock is in some cases still glassy, as in specimens from Boughilbrega, and contains microliths of felspar, magnetite, and augite; other examples are coarser grained (2227). These rocks yield 45 per cent. of silica on analysis. The lavas usually rest on volcanic ash, and indeed an almost continuous sheet of ash underlies the whole basin. The ashes rarely contain vesicular lapilli, but are usually made up of broken felspar and augite crystals, and bits of rock apparently broken up when solid (2233, 4).

The lower basaltic lavas are succeeded by others of *porphyrite*, purple in colour, much decomposed, and sometimes showing flat

porphyritic crystals of plagioclase felspar. Under the microscope the usual felt of plagioclase microliths is seen, containing porphyritic felspars, the relics of porphyritic augites, and pseudomorphs in specular iron and "iddingsite," which may be replacements of hypersthene, but are more likely to represent olivine (2224, 2230). If this determination turns out to be correct, the rocks may have to be called basalts. Unfortunately the only rock analysed could not be demonstrated to be a lava flow. It had a silica percentage of 60, and was much like one of the intrusive porphyrites.

The upper volcanic group is often founded on a bed of *ash*, and in the great outliers which occur to the north and north-west of the basin there are abundant beds of ash, with but few bands of lava. There is a perfectly gradual transition upwards from the limestone into the ash, which is displayed in the series of specimens exhibited (2258, 9, 3470). The upper part of the limestone contains at first a few scattered felspar crystals, then these increase in abundance until they form bands in the limestone, which become more frequent and thick until the rock is entirely made up of ashy material. *Breccias* and coarse bands are common (2256, 2265), and in some of them limestone blocks occur (2268). The prominent constituents are, however, vesicular lapilli, of what was once a basic glass, now converted into green palagonite (2257, 3470), while the vesicles are filled with calcite and chlorite (2260, 5). Occasionally a *tuff* is found, in which the fragments are embedded in a cement of pure carbonate of lime. This has probably been deposited by calcareous springs in the neighbourhood of the volcano (2261, 2). Many of the tuffs and ashes are quarried as building material for local use.

Some of the upper lavas, like those of Cahernarry (2248), Roxborough (2251), and Meelick House (2254), are *olivine-basalts* with porphyritic felspars, which can be seen with the naked eye (2248), and plagioclase, olivine, augite, and magnetite, which require the microscope; some of these still possess a glassy base (2250). There is, however, at least one lava flow on Nicker Hill (2242), and the same, or a similar one, at Knockseefin (2241), and Rathjordan near Ballybrood (2243, 4), which is devoid of felspar altogether, and consists of porphyritic crystals of augite and olivine (more or less altered) set in a plexus of minute augite laths. The augite crystals frequently show by their zones of growth that they were built up on a model like an hour-glass, the inner portions being green and the outer purple, with a colourless zone between the two (2242). The last substance to solidify has been a glass, which is now, however, devitrified. The rock appears to be an ancient example of the group of the *limburgites*, of which examples have been recognised by Dr. Hatch amongst the Carboniferous volcanic rocks of Central Scotland. The silica percentage of the rock is 38 (*c. f.* page 38).

The relics of sporadic volcanic outbursts are plentiful in the Limerick neighbourhood. There are *ash beds* and other volcanic

rocks near Cappamore (2274, 6), on the River Doon (2277), at Ballynahinch (773), Kilmoylan (2285), Knockavilla in Tipperary (2284), near Kanturk, where there are basic volcanic *ashes* full of palagonite lapilli (1713, 5), and at Carrigcleena (2288). The Hill of Knockfeerina, near Croome, which appears to be the site of an old volcanic neck, is made up of ash, *tuffs*, and *breccias* (2280, 1) with intrusive *basalts*.

PART III.

THE FOSSILS.

1.—GENERAL PALÆONTOLOGY.

PLANTS.

The vegetable kingdom is divided into two great groups—the flowering plants or Phanerogams, which bear a flower containing anthers and ovules, and the Cryptogams or flowerless plants. The Cryptogams were very much more important in ancient geological times than at present, and the earlier Systems have hitherto yielded no flowering plants at all.

CRYPTOGAMS.

These are divided into **Algæ**, including Diatoms and Seaweeds, **Fungi**, **Bryophyta**, including Mosses and Liver-worts, and **Pteridophyta**, including Ferns, Horsetails, and Club-mosses.

Algæ.—Some impressions which occur as low down as the Cambrian rocks are attributed to the remains of sea-weeds, and *Oldhamia* has by some observers been considered an Alga. There are, undoubtedly, true Algæ in the Lower Silurian Rocks, and from that time the division has continued to exist. The siliceous cases of diatoms sometimes form important rock masses, but these have not yet been found in Ireland (*v.* however p. 70).

Bryophyta are not at present certainly known from rocks older than the Eocene Period.

Pteridophyta.—Some Silurian plants belong to this series and are related to the living Rhizocarps and Lycopods. In the Devonian rocks appear the first known representatives of the Lepidodendra, Sigillarias, and Calamites, which became of such enormous importance in forming the coal forests of Carboniferous times. These three great groups die down after the Permian period, and are only represented at the present day by dwarfed individuals belonging to a small number of species.

PHANEROGAMS.

Gymnosperms.—This class appeared first in Devonian times, but the Mesozoic rocks contain remains of it in such abundance that the Era is called the age of Gymnosperms (or of Cycads). After the Lower Cretaceous Epoch the profusion of Gymnosperms rapidly diminished, but many genera flourish at the present day.

Angiosperms.—The Monocotyledonous division of this class first appeared in Jurassic rocks in forms related to the Screw-pines, and Palms appeared in the Cretaceous Period. The Dicotyledons appeared in the Upper Cretaceous Epoch, and thenceforward increased in number up to present times.

ANIMALS.

PROTOZOA.

In this, the lowest division of the animal kingdom, the body may consist of a single element or cell, or of an aggregate of cells, which do not differ greatly from one another; the cells retain their separate individuality, and are not combined to form a complex organism. There is no body-cavity and no nervous system.

The **Foraminifera** are the simplest forms known in the fossil state. The body is surrounded by a shell or test, through the mouth or the perforations of which long threadlike processes of the body (pseudopodia) reach the outside. The test may be horny, made of grains of sand cemented together, of carbonate of lime secreted by the animal, or more rarely of silica. The nature of the test is of use in classification. In the Imperforate division the shell is opaque and like porcelain, and the pseudopodia reach the outside through the mouth of the shell. In the Perforata the shell is pierced by pores through which the pseudopodia extend; it is glassy, and generally thin and transparent. Some foraminifera are simple, being globe- or flask-like in shape. More usually a number of single chambers are grouped together in a line, a spiral, or an irregular cluster, as in the well-known *Globigerina*.

Excluding *Eozoon Canadense*, once supposed to be a giant foraminifer, but which is probably not an organism at all, the earliest forms occur in the Silurian rocks, and steadily increase in number up to the present day, when enormous areas of the ocean floor are covered with a thick deposit of their remains, which are thus building up a vast limestone mass in some respects comparable to the Chalk. The Carboniferous Limestone and the Chalk contain immense numbers of fossil foraminifera.

The **Radiolaria** are not at present very extensively known as fossils, but almost every day new discoveries of fossil Radiolaria are being announced, so that the order bids fair to become a very important one, geologically speaking.

The Radiolaria are nearly related to the Foraminifera, but the central part of the body is separated from the rest by a membranous capsule. The skeleton in all the important fossil genera is a complex network of silica often furnished with projecting spines. These forms occur in Lower Silurian, and possibly in older rocks, for siliceous spherules, with the general appearance possessed by fossil Radiolaria, have been described from the slates of Howth and the Culdaff limestone. Like the Foraminifera they swarm in present seas, and the deeper parts of the Pacific and Indian Oceans are coated with an "ooze" formed of their skeletons.

They have also been found in the chert bands which occur in the Lower Silurian rocks on the coast of Down, a little south of Donaghadee.

PORIFERA.

This sub-kingdom is made for the reception of the sponges, which cannot be connected definitely with any other order, although they were originally placed with the Protozoa. They are multicellular, some cells being modified to form a membrane covering the exterior, others to drive water through the canals, to form the internal skeleton, or to serve as reproductive cells. Sponges have a canal system opening exteriorly in pores, often enlarging into globular chambers, and finding an exit into the central cavity of the sponge by openings there; the food passes from the outside along this system, and the excreta into the central cavity. An internal skeleton, either continuous or made of isolated spicules, is almost invariably present; it may be horny, calcareous, or made of siliceous fibres or spicules like the living sponge called the "Venus flower-basket." The earliest known examples of the sub-kingdom are found in Cambrian rocks, *Protospongia* being the most important genus found in them. *Ischadites* and *Receptaculites* found in Lower and Upper Silurian rocks are supposed to belong to the Hexactinellid sponges. Sponges attain an enormous development in the Jurassic and especially in the Cretaceous rocks, and exist in great numbers at the present day.

CŒLENTERATA.

These organisms are possessed of a definite alimentary cavity which communicates freely with the general body-cavity; the organs and especially the tentacles are arranged radially, and the cells of which the body is composed are arranged in two layers, an outer and an inner one, called respectively the ectoderm and endoderm. In the first great class, the **Hydrozoa**, to which the Graptolites and probably the Stromatoporoids belong, the alimentary cavity coincides with the body-cavity, and the reproductive organs are external; in the **Actinozoa** the alimentary cavity is separate from the general body-cavity, but communicates directly with it. The body-cavity is divided by radiating partitions, which carry on their surface the internal reproductive organs.

Hydrozoa.

The **Graptolites** are one of the earliest known groups of Hydrozoa. The animals or polypes (judging by analogy with their nearest living allies), consisted of cups or hollow cylinders with a mouth at the upper extremity surrounded by a circle of tentacles, whose function was to supply the mouth with food. A series of these cups was arranged in line and connected by a common substance or cœnosarc. The entire colony was surrounded by a covering of horny substance called chitin, similar in character to that which forms the horny fibres of a sponge or the wing-case of a beetle. The chitin was in the form of a tube, supported by a rod called the virgula, and giving off protective cups (thecæ) in which the individual polypes were lodged. This covering is of course the only portion preserved as a fossil, and when squeezed flat and in profile it has the appearance of a quill pen (hence the name), or a small saw. It is often the case that the graptolite is preserved in half profile or with the opening of the cups upwards, in each of which cases it presents a somewhat different aspect. More rarely, as in the beautiful examples from Barnane Hill, Tipperary, it is preserved in full relief, either the chitin is replaced, or casts of the interior of the cups are preserved, in iron pyrites forming a very beautiful object. When not preserved in relief the chitin is replaced by carbon. The animals are usually found in dark, fine-grained, shales, slates, or clays which have been formed in deep seas, but they are occasionally to be met with in limestones and volcanic grits.

Graptolites are found only in Palæozoic rocks and are even confined to a limited division of them, the earliest, *Bryograptus*, occurring in Cambrian rocks, the maximum development of the order taking place in Lower Silurian times, while it entirely died out before the end of the Upper Silurian Period.

The **Stromatoporoidea**, which are very common Silurian and Devonian fossils, probably belong to the Hydrozoa, but are said to have affinities with the corals. They have been supposed to belong the calcareous sponges or even to occupy a position between them and the foraminifera.

Actinozoa.

Corals.—These animals secrete a skeleton which in fossil forms is generally composed of carbonate of lime, and consists practically of a tube divided into compartments by radiating partitions which are usually present in multiples of 4 or 6. They reproduce themselves by eggs, by budding, the young forms growing upwards on the surface of the older ones, or by fission, the dividing of old polypes into two or more by partitions, so that a large colony is speedily established; as this continues alive at the surface, eventually a large mass is built up. When calcite is deposited in the interstices of the corals, and when the spaces are filled up and supplemented by detrital coral rock a reef is formed. As modern reef-building

corals cannot live in deep water, the presence of fossil reefs suggests that the surface, at any rate, on which the animals lived was probably not beneath more than 15 fathoms of water.

The corals, so far as is at present known, begin their history in Lower Silurian times and have continued in undiminished numbers to the present day. The older types of corals belong to the Rugosa or quadri-radiate division or else to the old division of the Tabulata whose members are now distributed between the Perforate division of the Madreporaria and the order of Alcyonaria. The Rugosa seem to be confined to the Palæozoic Era, while the Alcyonaria have so much changed their appearance that it was at first not easy to see the relation of the older corals to them. In Mesozoic times the sex-radiate types belonging to the Aporosa or Fungidæ were much more common, and these, with the Madrepores, are the principal builders of the coral reefs of to-day. The chief masses of coral limestone in Ireland are found in the Carboniferous Limestone, but others occur in the Silurian limestones such as those of Kildare and Lambay Island, Portraine, and Clogher Head (Kerry).

Echinodermata.

In this division of the animal kingdom we reach forms which are provided with distinct nervous, vascular, and water-vascular systems. Usually they are radially symmetrical in their parts, and are protected by an armour of calcareous plates or spines from which they derive their name, which means prickly skin. To the Echinoderms the following classes belong:—The starfishes or **Asteroidea**, the brittle stars or **Ophiuroidea**, the sea urchins, **Echinoidea**, and the sea lilies including the **Crinoidea**, **Cystoidea**, and **Blastoidea**.

Asteroidea and Ophiuroidea.—The animals of both these classes are generally pentagonal in outline and are possessed of a central disc with five or more appendages or arms. In the first class the body of the animal is prolonged into the arms, in the second the arms are mere appendages. The animals are so well covered with calcareous plates that they are admirably preserved in the fossil state, and their remains are known in all the rocks from the earliest Lower Silurian time up to the present day; no prevailing differences are observable, to separate the oldest types from those still surviving.

Echinoidea.—This class of the Echinodermata which includes the well-known sea-urchins is characterized by the possession of a globular, heart shaped, or disc-like body enclosed in a test composed of a number of calcareous plates fitted together at their edges. The mouth is on the under part of the body and is usually armed with a number of calcareous teeth. The anus is either at the apex of the test when the urchin is called regular on account of its symmetrical shape, or else at some position between that and the mouth, when it is termed irregular. The reproductive organs are

internal and communicate with the surface through a perforated plate at the summit of the shell. The test in existing forms is composed of twenty rows of plates arranged in alternating pairs, of which one set is perforated by pores, penetrated by little tubes or "*tube feet*" by means of which the animal moves, and hence called ambulacral areas, while the other set are not perforated and are called interambulacral areas. The ambulacral areas converge at or near the apex, and give rise to a petaloid or pentagonal star-like figure which may be continued round the test to the mouth. The interambulacral area is invariably provided with small or large spines articulated by a ball joint to the plates of the test and in some genera the ambulacra are similarly provided.

The Palæozoic urchins have a "regular" test, but it is made up of more or less than twenty rows of plates; for instance, in *Palæchinus*, each interambulacral area is made of five rows, and in *Melonites*, both ambulacral and interambulacral areas have eight or nine rows of plates. In these ancient forms the individual plates are often bevelled off so as to articulate with one another, and give more or less flexibility to the test.

The rest of the regular urchins belong to Neozoic and present time, and have as a rule rigid tests with never more than twenty rows of plates; in the Echinothuridæ, however, the plates overlap so as to make the test flexible. The irregular Echinoidea to which belong such genera as *Micraster*, *Holaster*, and *Echinoconus* are unsymmetrical, pentagonal, or heart-shaped in outline, the anus being excentric and situated on the upper or lower surface of the test, or on the margin between the two.

Crinoidea.—In this class of the Echinodermata the body is fixed to the sea bed during some portion of its existence by a flexible stalk. The body consists of a disc in which the principal part of the alimentary, blood, and water-vascular systems is situated. It gives off primarily five arms which often branch again and again, so that there may eventually be hundreds of arms fringed with pinnules, each of which is engaged in providing the mouth with food. The dorsal side of the body is protected by calcareous plates, the ventral sides by plates or granules, and the dorsal plates are arranged in the form of a cup which is set on a jointed calcareous stem; it is this general appearance which has obtained the popular name of sea or stone lilies for the class. In some genera the protection of the ventral surface is continued upwards into a "proboscis" at the summit of which is the anus.

The earliest crinoids are found in the Cambrian rocks, and after attaining a maximum in Upper Silurian and Carboniferous times they gradually die down till only a few, mostly free-swimming, genera survive to the present day. The Crinoids found in Palæozoic rocks for the most part have the radial plates (those which support the arms), firmly welded together, while in the Mesozoic forms, which first appear in the Triassic rocks, and are the only existing type, the higher radials are

articulated and moveable. The remains of the stems and arms of these animals occur at times so abundantly as to make up whole beds of limestone, and this is especially the case in the Silurian and Carboniferous limestones.

Cystoidea and Blastoidea.—The two Palæozoic classes of Cystoids and Blastoids are closely related to the Crinoids. In the former there is generally a short stem, a body with little radial symmetry and feebly developed arms. This class ranges from the Cambrian to the Carboniferous rocks. In the latter the animal is contained in a cup formed of calcareous plates and fixed upon a jointed stalk, but there are no free arms, only grooved areas radiating from the summit of the calyx and these carry jointed pinnules. The class is confined to Palæozoic rocks and does not survive the Carboniferous Period.

VERMES.

In this group the body is divided into a number of segments arranged behind one another; a nervous system is present and generally limbs. The group comprises the worms, numbers of which are represented in the fossil state, particularly that division in which the body is protected by a calcareous or arenaceous tube. Such forms are met with all through the strata and especially in Lower and Upper Silurian, and in Carboniferous rocks.

Those worms which have no skeleton of any kind are known to us only by the relics of their burrows or casts, or by the tracks they make in travelling over soft sand or mud. A great many tracks referred to the annelides probably have been made by other animals such as Crustacea and Trilobites, even by Molluscs, while some may be the impressions of fucoids and other plants.

ARTHROPODA.

In this large sub-kingdom the body is divided into a number of segments longitudinally arranged, each segment bearing a pair of appendages or limbs which are usually jointed and serve as antennæ, maxillæ, mandibles, and organs of prehension or locomotion.

Crustacea.

Merostomata.—The Eurypterids were large crustaceans, most of whose abdominal segments were devoid of limbs. They occur in rocks from Upper Silurian to Carboniferous age, some of the specimens from the Old Red Sandstone being over six feet in length. Some details of their organization suggest a link between them and the Scorpions.

The King-crabs (*Limuli*) are related to Eurypterids by such intermediate forms as *Hemiaspis* and *Prestwichia*. They have a superficial resemblance to trilobites but the abdominal segments are fused together into a post-cephalic shield. They have continued to exist from Silurian to present times.

Trilobites.—This order is more than any other characteristic of Palæozoic time. The body of a trilobite is covered with a horny coat which is divided into three lobes, laterally, and into segments like those of an insect or lobster longitudinally. Each individual segment consists of a central or axial portion and two lateral portions called pleuræ. The whole of the front segments are welded together into a single head or cephalic shield which usually shows a projecting central portion or glabella that contained and protected the stomach, with lateral portions supporting the eyes, often compound, when they are present, the antennæ, and other appendages. The rings of the thorax are free and articulated together and vary in number from two in *Agnostus* to 20 in *Paradoxides*. The segments of the tail, or pygidium, are welded together, but the markings on this generally indicate the number of segments of which it is constructed. Few examples of trilobites showing limbs have up to the present been discovered, but there is evidence of the existence of antennæ and of four pairs of other appendages, probably all attached to the labrum or lip plate. The bases of these latter were modified to act as mandibles. Each ring of the thorax was provided with a pair of jointed limbs for walking and swimming, which probably bore attached at their base spiral appendages in the nature of gills.

The larval development of certain forms of trilobites has been studied by Barrande and others, who have shown that one part of the body is usually less developed than another, either head, tail, or thorax being at first very incomplete. The growth of the individual thus to some extent recalls that of the order; the earlier trilobites show a disproportionately large or small number of rings in one or other part of the body. Thus in *Olenellus* and *Paradoxides* the tail is very small compared with the head, while in *Agnostus* the thorax is reduced to a couple of rings; the earliest trilobites are possessed of abnormally large eyes or else are entirely devoid of them.

The order begins in the earliest Cambrian rocks, its numbers increase in the later divisions of the System, attaining a maximum of individual and specific development in the Lower and Upper Silurian Systems. From that maximum the order gradually waned in the Devonian System until only four genera are found in the Carboniferous, and but one in the Permian rocks.

The **Phyllopoda** have never less than eight pairs of feet and frequently many more; the animal is enclosed in a bivalve shell or carapace; the feet are mostly leaf-like in shape and are modified to serve as gills for breathing purposes. The order is found in Cambrian strata, becomes especially numerous in the Silurian rocks, and survives to the present day.

The **Ostracoda** are provided with only a small number of feet, and the whole body is enclosed in a minute bivalve shell which is often found preserved as a fossil. The general range is from the Cambrian Period to the present day.

The **Decapoda** are only of occasional and local importance in the fossil state, although their outer skeleton, made of chitin more or less strengthened by calcareous deposit, fits them admirably for preservation. The tribe to which the lobster belongs came in for the first time in Devonian times and is but sparingly represented amongst fossils. The crabs appeared later, in the Jurassic rocks, and are tolerably common in Tertiary strata.

Arachnida, Myriapoda, and Insecta.

These classes are not very numerous as fossils. The arachnids, to which scorpions and spiders belong, are met with occasionally in Silurian and later rocks, especially in those belonging to the Carboniferous System. Insects are fairly common in certain beds adapted, from their mode of formation or their lithological character, to receive and retain impressions of them. Their remains have been found in rocks ranging from the Silurian Period to the present day.

MOLLUSCOIDEA.

This sub-kingdom is made for the reception of the Polyzoa and Brachiopoda—not that these two classes have much in common, but that they may be conveniently considered between the Vermes and true Mollusca. They are soft-bodied animals, the bodies not being segmented, but usually surrounded by a hard calcareous or horny covering; the alimentary cavity is always distinct from the general body cavity; the nervous system is confined to a single ganglion or pair of ganglia, and the heart is imperfect or absent.

Polyzoa.

These are compound animals consisting of a number of similar individuals called polypides united into colonies by their external integument which usually secretes a calcareous coating, the general appearance of which when found in a fossil state is a mat of carbonate of lime pierced by larger and smaller openings in which the polypides are situated. The soft parts consist of an alimentary canal inside the general body cavity, and terminated upwards in a mouth fringed with tentacles. They are sometimes found separately but more frequently encrusting shells and corals. At the present day the Polyzoa are mostly marine and they have been found in all rocks from the Lower Silurian up to the present day. The older forms belong to genera not provided with an operculum to close the openings of the shell.

Brachiopoda.

The Brachiopoda are not at present of much use in indexing the minor subdivisions of strata, although there is little doubt that they will eventually become very serviceable for that

purpose. They are never compound like the Polyzoa, although somewhat similar to that division in general structure. The animal, whose "mantle" lines the shell which contains it, has a mouth furnished with long, spirally coiled, "arms," which are lined with cilia whose function is to carry food to the mouth. The larger valve contains the greater part of the animal, and is termed the ventral valve, while the other is spoken of as dorsal. The result is that the two valves, being upper and lower in position, are unlike in shape (inequivalve), but as the animal is symmetrical, with its right and left halves alike, each valve is symmetrical (or equilateral). The "beak" or projecting portion of the ventral valve is usually pierced by a hole through which passes the muscular filament by which the animal is attached to stones, shells, or the sea-bed. The interior of the shell is usually provided with some contrivance for supporting the parts of the animal, particularly the complex, food-providing, arms. This support takes many different forms: In *Orthis* and *Producta* the thick mass of the valve is sculptured to receive the arms and muscles; in *Meristella* there is a process shaped like a shoe-horn; in *Pentamerus* a number of plates dividing the shell into five nearly closed chambers; in *Spirifera* and *Athyris* spiral processes of various forms; but in *Terebratula* and other Mesozoic genera there is some modification of the "loop" or "carriage-spring apparatus." As a rule the more complex contrivances are found in Palæozoic genera, while the loop occurs in the genera of later rocks.

The two principal divisions of the Brachiopods, the **Inarticulata** (or Tretenterata) and the **Articulata** (or Clistenterata) are to be found in the Cambrian rocks. In the first division the valves of the shell are not united by a hinge. The Articulata have a defined hinge. The first division has not varied much in numbers throughout geological time, the second was very rich in numbers, both of individuals and species in Silurian, Old Red, and Carboniferous time, certain genera were important in the Mesozoic era, but on the whole the division dwindled down to the present day.

Mollusca.

This sub-kingdom is in advance of that previously described in that the nervous system is composed of three principal pairs of ganglia united by cords and prolonged into nerves, whilst there is a well developed heart consisting of two or usually three chambers. Respiration takes place by means of gills except in terrestrial forms which are provided with a pulmonary sac or lung. The shell is usually external, but sometimes it is in the form of an internal skeleton, while at times it is altogether absent; the organism is never compound. The sub-kingdom is divided into four classes, of which the Lamellibranchiata are headless, while the Gastropoda, Pteropoda, and Cephalopoda possess heads, the last division standing on a higher plane than the rest of the sub-kingdom.

Lamellibranchiata.

The Lamellibranchiata or Pelecypoda are the lowest class of the Mollusca proper. The body is protected by a shell made of two pieces or valves. The animal usually rests on the beaks of the valves on the sea-bed, so that the valves are not dorsal and ventral as in the Brachiopods, but right and left in position. In consequence, one valve is the symmetrical counterpart of the other, and the shells are equivalve but not equilateral. The chief points of organization which are of classificatory value are the following:—The presence or absence of a siphon and its retractile character or otherwise; the number and relative importance of the adductor muscles, and the consequent marks of their attachment to the shell; the nature of the attachment of the mantle edge to the shell, as indicated in fossil shells by the pallial line impressed on the shell; such a line is either a simple or an indented curve. The shape and ornamentation of the shell, the presence and number of hinge teeth, the lunule or space behind the beaks, and the hinge area, are other important points to be observed.

The division of Lamellibranchiata makes its appearance in the Cambrian rocks, but very few genera are found there. They gradually increase in number up to the present day, when there is probably a larger number of species than at any previous time. In many cases Palæozoic genera have become extinct, but most of them have rather close allies in the seas of to-day. The bulk of Mesozoic and Cainozoic genera belong to the **Siphonida**, and of the Palæozoic forms to the order of **Asiphonida**.

Gastropoda.

This class of the shellfish possesses a distinct head provided with eyes, and is confined within a single shell which is usually a hollow cone coiled on itself in a right-handed spiral, very rarely divided by partitions, and only in certain genera closed by a horny or calcareous door called an *operculum*. The features of classificatory importance chiefly depend on the structure of the soft parts of the animal, some of which, however, influence the shape and character of the shell. The chief fossil forms belong to the order **Prosobranchiata**, in the modern genera of which the gills and auricle are in front of the ventricle of the heart. The lip or edge of the shell is entire in the older forms, indicating that the animals were vegetable feeders, and were not possessed of a siphon for carrying aerated water to the gills. The later forms have often one or more canals, which carry the siphon, at the lip of the shell. These are mostly Carnivorous, but both types survive in great numbers to the present day.

The **Pulmonata** or lung bearing shellfish, to which division the land and freshwater snails belong, have usually a simple shell. The **Pteropods** or wing-footed shellfish live on the surface of the sea, and consequently their remains are found at all depths, while

certain deep-sea oozes are largely made of their remains. The shell is generally a simple cone, and examples of the group are found as early as in Cambrian time.

The Gastropoda are comparatively rare in the lower Palæozoic rocks, but are present in very considerable numbers in the Carboniferous. They are again very characteristic of the Jurassic and Cretaceous rocks, while tropical and sub-tropical genera abound in the Tertiary strata. They are perhaps more abundant at the present time than ever. The land and freshwater types have varied very little since Carboniferous times, but from the nature of their habitat they are not very common as fossils.

Cephalopoda.

This division stands at the head of the *Mollusca*, but is less frequent in the seas of to-day than it has been in the past. The Cuttlefish, Nautilus, and Argonaut are amongst the few living types, and in them the animal possesses a distinct head, with a mouth surrounded by tentacles, and two large eyes, generally well developed; in some forms there is an ink bag. The most important fossil genera are referred to the **Tetrabranchiata**, represented now by *Nautilus*, possessing two pairs of gills and enclosed in a chambered shell which is enlarged as the animal grows, the hinder part being partitioned off into chambers. The more important Palæozoic genera like *Orthoceras* and *Nautilus*, which came in in Silurian times, became extinct or much diminished in numbers in Mesozoic times and were replaced by enormous numbers of the great *Ammonite* genus which in turn became extinct in the Tertiary rocks after developing many extraordinary modifications in Cretaceous time. The two-gilled order, **Dibranchiata**, is represented in the Secondary rocks by a great abundance of the guards of *Belemnites*, a genus allied to the modern *Sepia*, which became extinct at the end of Cretaceous times. This order of the Cephalopoda is the one most frequent in modern times, *Nautilus* being the only surviving tetrabranchiate form.

Vertebrata.

The members of this sub-kingdom have an internal bony skeleton which supports a nervous system composed of brain and spinal chord. They never have more than four limbs, which are turned towards the ventral aspect of the body. The sub-kingdom is divided into five principal classes, of which the Fish stand lowest and the Mammals highest in the scale of life.

Fish.

The oldest known fish occur in the Silurian rocks in which spines and dermal plates belonging to Selachians and Ganoids have been found. In the Selachians, the Dipnoi, and in the older Ganoids, the inner skeleton is cartilaginous throughout

life, while the outer skin is protected by isolated granules, tubercles, and spines, or by a continuous covering of bony scales. The **Ganoids** attain their maximum in the Old Red rocks, are fairly represented in the Secondary rocks, but exist only in very small numbers at the present day. The number of **Selachians** does not appear to have varied much in past time. The **Dipnoi** or mudfishes, the nearest to the amphibians in structure and in the fact, amongst others, that the air sac is modified to act as a lung, make their appearance in Devonian times, existed in great numbers in Triassic time, and then died down until they are all but extinct at the present day. The **Teleosteans**, or bony fish with a perfect internal bony skeleton, the highest order of the class, do not make their appearance till the Cretaceous Period.

Amphibia.

The Amphibia come next in the scale. They breathe by gills in the earlier part of their lives, but two lungs are always present in the adult. No amphibians, except these belonging to the Labyrinthodont order, are known from rocks older than Tertiary, but this order is of great importance in the Carboniferous, Permian, and Jurassic Periods. Examples of these will be noticed under the Upper Carboniferous fossils of Ireland.

Reptilia.

The animals of this order, which never pass through the early water-living stage of the Amphibians, breathe by lungs throughout their whole existence. Of the ten orders into which the sub-kingdom is divided, no less than six are extinct, and it reaches the acme of its development in Mesozoic times. It is possible that the earliest reptiles are Carboniferous, but in the Permian strata they undoubtedly occur. In the Mesozoic rocks occur Ichthyosaurs, Plesiosaurs, Pterodactyles, Deinosaurs, and Anomodontia, and to such rocks their remains are confined ; but the ancestors of existing Chelonia (Tortoises) and Crocodiles appear also in these rocks. The Ophidians (Snakes) are the only order at present not known to be older than the Tertiary period.

Birds.

About these the rock record has little to tell, for they are very rarely preserved as fossils. That little, however, is of surpassing interest, for the Mesozoic forms, the Saururæ and the Odontornithes, approach on the one hand such reptiles as the Pterodactyles, and on the other the Deinosaurs, in the shape and character of their limbs, brains, or tails, in the possession of true teeth in the jaws, and in the general configuration of the skeleton. No fossil birds older than the Jurassic Period are known, whilst those of the Tertiary Era make a much closer approach to those existing at the present day.

Mammalia.

This division, to which the ordinary so-called quadrupeds belong, is but rarely found fossil, except in the Tertiary rocks. It is true that a few species have been found at exceptional localities in the Triassic and Jurassic rocks, but the great evolution of the families and genera of the Mammals took place in Tertiary time. It is possible to trace back some of our existing species, and to find links between these species in Pliocene times, links between existing genera in Miocene times, and between what are now entirely separate families in Eocene times. It is thus possible to work out the actual line of descent of many of our living species from ancestors which are less specialised and more and more generalised in character the further we go back in Tertiary time. Man, the highest of the Mammals, has left traces of his bones, implements, and dwellings at different periods, but the earliest of these have not been yet traced back with certainty to any period earlier than Pleistocene, and not indeed to the older part of that period.

2. THE PALÆONTOLOGY OF IRELAND.

The Collection of Fossils is arranged in historical (chronological or stratigraphical,) order, the oldest being placed first at the south end of the gallery and progressively newer forms along the cases towards the north, where the youngest are to be seen. The large labels in each case show the particular geological formation or horizon from which the surrounding specimens have been obtained. The following key will show at a glance the method of arrangement. The numbers refer to the flat *table-cases* which are placed across the room and in the windows, and to ten *cases* and a series of *pedestals* on the west side of the room.

Case.	Systems and Series.
1.	Pre-Cambrian?
2.	Cambrian.
3-9, in part.	Lower Silurian, including some Upper Silurian.
9 rest -10.	The Portlock Silurian Collection.
11-13.	Upper Silurian.
14, 15, 45, 49.	Old Red Sandstone.
16-26, 42, 46, 48, 50.	Lower Carboniferous Rocks, and Carboniferous Limestone.
27-33, 38, 41, 43, 44, 46, 50.	Yoredale Series to Coal Measures.
34.	Permian, Trias, Rhætic.
34, 35, 46.	Lias.
36, 37, 46, 51, 52.	Cretaceous.
39.	Eocene or Oligocene.
40, 50, 53.	Post-pliocene to Recent.

Within each of the divisions thus specified the fossils are arranged zoologically, according to their place in the scale of life, the lower forms being placed to the left and the higher towards the right. On the labels at the bottom of each tablet will also be found the more exact horizon from which a fossil has been obtained, when this can be accurately ascertained or defined. *Type-specimens, figured and described* in the Survey Memoirs and elsewhere, are deposited in a special case in the general Palæontological department of the Museum, and the *Portlock Types* are in the Museum of Practical Geology in London.

Case I.—Fossils in Strata associated with Foliated Rocks.

In this case have been placed the radiating masses of crystalline carbonate of lime, which display a structure rudely approximating to that of *Favosites*, *Halysites*, *Columnaria*, and other Corals. They have been considered by Professor Hull and other observers, since their discovery by Mr. Patrick Ganly in 1856, as belonging to one or other of these genera. Their chief interest is that they occur in rocks of great but unknown age—limestones interbedded with the quartzites and schists of Culdaff, in Donegal. It should be noted, however, that in the magnesian limestone of Durham undoubted, inorganic, radiating, calcite-concretions occur, which mimic organic forms much more closely than these; and it is possible that eventually the affinities of the Culdaff forms will be found to lie with them. On the other hand the discovery of possible Radiolaria by Professor Sollas in the same limestones (referred to on page 97) indicates the strong probability that fossils will eventually be found in these rocks. In black slates from the same county, about Fintown, Mr. M°Henry has also found markings, too obscure for generic determination, which look like distorted Graptolites, and which, if they really turn out to be graptolites, are likely to indicate that the rocks containing them are of Lower Silurian age, as they appear to belong to the *Diplograptidæ*.

Case 2.—Cambrian Fossils.

Many years ago a singular organism was found in the Cambrian Rocks of Howth and Bray. It was named *Oldhamia* after Dr. Thomas Oldham, at that time Director of the Geological Survey of Ireland. Much discussion has arisen as to its true nature. It has been referred to various grades in the animal kingdom—a sertularian zoophyte, a graptolite, or a polyzoan; by some writers it has been considered to be a plant, possibly one of the calcareous seaweeds, while some have even suggested that it is an inorganic structure possibly connected with the crushing or shrinking of the beds which contain it. It consists of fans of thread-like branches sometimes springing from a central axis at regular intervals.

Three species of this organism, *Oldhamia radiata*, *O. antiqua*, and *O. discreta*, have been distinguished, and specimens of them will be found in case 2.

The grit rocks in the Irish Cambrian System are frequently marked by burrows attributed to the action of worms or other annelids. *Arenicolites* consists of burrows in the form of a U, *Scolithus* forms long, straight, vertical burrows, while *Histioderma* is a curved burrow opening with a trumpet-shaped mouth on the surface of a small mound. Tracks and what are supposed to be casts of the interior of worms also occur. Professor Sollas has recently figured and described under the name of *Pucksia MacHenryi* certain small, crushed, cylindrical, bodies, doubtless organic, which occur at Pucks Rocks on Howth.

The trilobite faunas of the Cambrian rocks have not yet been discovered in Ireland; the oldest fauna is that distinguished by the occurrence of *Olenellus*, the second (the Harlech beds in part and the Menevian series of Wales) by *Paradoxides*, *Agnostus*, and *Conocoryphe*, the third (including the Lingula Flags and Tremadoc Slates) by *Olenus*, *Asaphellus*, *Angelina*, *Neseuretus*, and *Niobe*.

Cases 3–13.—Silurian Fossils.

The fossils shown in cases 3–13 are divided into three sets:—(1) Those from areas mapped by the Survey as Lower Silurian but including probably Upper Silurian rocks as well; cases 3–9; (2) the Portlock collection from Londonderry, Tyrone, and Fermanagh, and a number of other localities which are referred to, with figures and descriptions of type specimens, in the "Geology of Londonderry," cases 9 & 10; (3) those from undoubted Upper Silurian areas, cases 11–13. Beginning in case 3 with Plants and Graptolites the scale of life rises until case 10 with its Cephalopoda is reached.

The Plants are very imperfect and may be merely fucoidal markings; they are from Tipperary. A doubtful **Sponge** from the black shale of Waterford is also exhibited in this case.

The Graptolites give evidence that the Silurian rocks of the country may be split up into smaller divisions than are recognised at present. Indeed the work done by Lapworth and Swanston has already borne fruit and the zones recognised by them are now being followed and mapped by the officers of the Survey towards the south-west. The Graptolites from the Arenig Series are highly complex forms made up of a branching group of "single pens" or monoprionidian forms. These types are possessed of only a single row of thecæ placed on one side of the cœnosarc. The primary branch divides into two, each of these into two more, and so on until a single colony may contain hundreds of branches. This is the case with *Dichograptus*, *Tetragraptus*, and *Loganograptus*. Occasional forms occur which consist of two single pens joined together to form a "double pen" as in *Diplograptus*, but this genus

is not common in such early rocks. A more common Arenig form is *Phyllograptus* which has four such "pens" united "back to back."

The branching is not carried so far in Upper Arenig and Lower Llandeilo rocks, where singly branched forms like *Didymograptus* and *Dicellograptus* are met with. Thus *Didymograptus Murchisoni*, occurring at Bellewstown with *Diplograptus foliaceus*, indicates a Lower Llandeilo age for these beds. The higher Llandeilo or Lower Bala beds are characterized by the slender graptolites *Leptograptus* and *Cœnograptus*. *Climacograptus bicornis*, *Cœnograptus gracilis*, *Didymograptus Hisingeri*, *Dicranograptus ramosus*, *Dicellograptus sextans*, and *Leptograptus flaccidus*, have been obtained from the Ballygrot beds of Down, from Tramore at Gibbet Hill, and the river Suir in Waterford, Ballymore and Gorey in Wexford, Six-mile-bridge and Belvoir in Clare. The Bala beds at Carnalea and near Saintfield in Down, near Poyntzpass in Armagh, and near Slane in Meath, have yielded *Climacograptus bicornis*, *C. Scharenbergi*, *Cryptograptus tricornis*, *Dicellograptus Forchhammeri D. moffatensis*, *Dicranograptus Clingani*, *Diplograptus perexcavatus*, and *D. truncatus*.

The Llandovery rocks are marked by the appearance of Monograptidæ, such as *Monograptus*, *Cyrtograptus*, and *Rastrites* and the gradual diminution of the Diplograptidæ. The Llandovery rocks of Coalpit Bay contain *Climacograptus normalis*, *Dimorphograptus Swanstoni*, *Monograptus gregarius*, *Rastrites peregrinus*, and *Retiolites perlatus*. Similar forms occur near Dromore in Down, near Poyntzpass in Armagh, and E. and N.E. of Slane in Meath.

Somewhat higher beds are indicated at Tieveshilly, Pomeroy, and Lisbellaw by such species as *Monograptus Hisingeri*, *M. priodon*, *M. riccartonensis*, and *M. turriculatus*; while strata with a Tarannon fauna occur at Hillsborough and elsewhere in Down, and at Salterstown in Louth.

Beds containing *Monograptus priodon* and *M. Sedgwicki* occur near Balbriggan and on Lambay, while *Cyrtograptus* and *M. priodon* are found at several places in Clare and Tipperary, proving that Upper Silurian (Tarannon or Wenlock) rocks rest on the Lower Silurian rocks there. Fine specimens of *M. priodon* from Barnane Hill in Tipperary occur perfectly uncrushed in a dark grey limestone, while one specimen over a foot long was obtained from Gortbrigane in the same county. Specimens of most of the forms mentioned will be found in cases 3, 4, 9, and 11.

The **Corals** are represented by such genera as *Halysites*, and *Heliolites* belonging to the Alcyonaria, *Favosites* to the Perforata, *Cyathophyllum*, *Acervularia*, *Omphyma*, *Petraia*, and *Zaphrentis* to the Rugose division; they have been found in Dublin, Kildare, and Waterford.

The subdivisions indicated by the Graptolite faunas are borne out by the **Trilobites** where they happen to occur in the same or

in interbedded rocks. These have, however, not yet been worked out with sufficient minuteness to indicate the minor Series and Stages, but only to show in a rough way that the rocks of any particular locality are Lower or Upper Silurian. Thus the species of *Asaphus*, *Ogygia*, *Ampyx*, *Illænus*, and *Trinucleus*, from Waterford concur with the Graptolites in indicating that the rocks there are of Llandeilo age and the same is probably true of the fossils from Enniscorthy. Species of *Sphærexochus*, *Illænus*, *Lichas*, *Cheirurus*, and *Cythere* from Kildare are equally emphatic in pronouncing the rocks there to belong to the Bala series of the Lower Silurian System; while the fossils from Meath, Balbriggan, and Portraine indicate that rocks of the same age occur in those areas. Specimens of these and other forms will be found in cases 5, 6, and 9.

On the other hand, the Trilobites from localities in Dingle, Clare, and Tipperary, in case 11, including *Acidaspis*, *Calymene Blumenbachi*, *Proetus latifrons*, *Phacops caudatus*, *Encrinurus punctatus*, *Lichas anglicus*, *Leperditia subrecta*, seem to show that the rocks here are of Upper Silurian age, particularly as they are associated with *Pentamerus Knightii*, *P. galeatus*, *Rhynchonella Wilsoni*, *R. llandoveriana*, and *Spirifera bijugosa*.

The Silurian **Echinoderms** include *Palæaster Kinahani* and *P. ramsayensis*, from the rocks of the Bannow coast in Wexford (case 5), where the apparently interbedded rocks have yielded specimens of *Oldhamia*. Heads and stems of *Actinocrinus*, and Cystideans like *Echinosphærites* are also placed in the same case.

Polyzoa and Brachiopoda are placed in case 7, many of the latter having been obtained from the Chair of Kildare and the shore at Portraine. The latter include *Orthis*, *Strophomena*, *Porambonites*, *Siphonotreta*, *Atrypa*, *Leptæna*, *Lingula*, *Obolella*, and *Discina*; other Brachiopoda, chiefly Lower Silurian, are placed in case 8, followed by **Pteropoda**, including *Theca* and *Conularia* from Dublin, Meath, Waterford, &c., **Heteropoda**, *Bellerophon perturbatus*, from Wexford and Waterford, and **Gastropods** from the Kildare limestone and from Wexford and Tipperary, including *Acroculia*, *Euomphalus*, *Raphistoma*, *Holopea*, *Turbo*, *Murchisonia*, *Patella*, and *Cyclonema*.

In case 9 are placed the Lower Silurian **Cephalopoda**, *Orthoceras*, *Cyrtoceras*, and *Lituites* from Dublin, Kildare, Wexford, Waterford, and Tipperary, fucoidal markings and annelid tracks from Tipperary, and the problematical *Nidulites* from various localities. The rest of the case, and the whole of case 10, contains the Portlock collection, with the exception of the forms figured and described in the "Geology of Londonderry."

Fossils from those areas definitely recognised as Upper Silurian have been arranged in case 11. **The Graptolites** from Dingle in Kerry, supplemented by others from Galway, Clare, and Tipperary, are chiefly single pen (or monoprionidian) forms, including *Cyrtograptus* and *Monograptus*. A beautiful set of **Corals** from the same localities, comprises *Petraia*, *Cyathophyllum*, *Favosites*,

Zaphrentis, *Heliolites*, *Halysites*, *Syringopora*, *Aulopora*, *Stenopora*, *Nebulipora*, and *Omphyma*. **The Echinodermata** include *Actinocrinus*, *Cyathocrinus*, and *Glyptocrinus*, and the **Trilobites**, *Acidaspis*, *Calymene*, *Proetus*, *Encrinurus*, and *Lichas*. Annelides and Polyzoa are in the same case. **Brachiopods** fill case 12, including the following important genera—*Lingula*, *Pentamerus*, *Orthis*, *Rhynchonella*, *Spirifera*, *Leptæna*, *Athyris*, *Chonetes*, *Atrypa*, and *Strophomena*.

Case 13 contains Mollusca, comprising—*Avicula*, *Pterinea*, *Cardiola*, *Grammysia*, *Orthonota*, *Cucullella*, *Modiolopsis* amongst the **Lamellibranchs**, a few species of Heteropods and Pteropods, several genera of **Gastropods**, *Trochus*, *Turbo*, *Loxonema*, *Murchisonia*, *Euomphalus*, *Acroculia*, and a collection of **Cephalopods**, including *Orthoceras*, chiefly from Kerry, Galway, and Tipperary

CASE 14–15, 45 AND 49.—OLD RED SANDSTONE FOSSILS.

These rocks in Ireland, as well as in England and Scotland, are singularly barren in organic remains, those which have been found being the relics of land and water vegetation or such shells, crustacea, and fish, as lived in freshwater lakes. From this it is argued that the rocks were deposited in great lakes.

Lower Old Red Sandstone.—In the left hand side of case 14 there are a few specimens of fossils found in the pebbles which make up the Parkmore conglomerate of Kerry, a band in the Lower Old Red Sandstone or Dingle beds of that locality. They have been almost certainly derived from the denudation of some Silurian rocks, possibly of Llandovery or Wenlock age. They are *Orthis elegantula*, *Cyathophyllum truncatum*, and Crinoid joints.

Upper Old Red Sandstone.—The rest of case 14, and the whole of 15, are occupied by a fine collection of plant remains from the well-known quarry at Kiltorcan Hill, near Ballyhale railway station in Co. Kilkenny. It comprises specimens of the beautiful fern *Palæopteris hibernicus*, and also the cryptogam *Knorria bailyana*, of which portions of the root, stem, and spore cones are represented. Large specimens of this species, with *Cyclostigma kiltorkense*, *Anodonta Jukesii*, and *Coccosteus* will be found in cases 45 and 49. There are also a few plant remains from Cork and Waterford. In addition to two specimens of *Palæopteris hibernicus* at the left hand end of case 15 (see also 45), this case contains a collection of Fish remains, chiefly the bony head-plates of *Coccosteus* and other genera, and examples of freshwater Crustacea, such as *Pterygotus hibernicus*, *Limuloides kiltorkense*, and *Proricaris M'Henrici*. A fossil of much interest is *Anodonta Jukesii*, related to the modern freshwater mussel, which suggests the probable mode of formation of the deposit containing it. All these specimens are from Kiltorcan. (See also frame 45).

Cases 16–19—Lower Carboniferous Fossils.

The Lower Carboniferous Sandstones and their associated shales and limestones are in places richly fossiliferous, the remains being generally of shallow-water, marine, forms, marking the first advance of the sea which was to spread so widely over Ireland, and give rise to the thick and wide-spread Carboniferous Limestone Series. Case 16 contains plant remains from the Coomhola grits and Carboniferous Slate of South Ireland, and some from the Carboniferous Sandstone Series of Antrim and Galway. Crustacea are represented by **Ostracods**, such as *Leperditia*, **Trilobites**, including *Phillipsia pustulata*, and the remarkable **Phyllopod** *Dithyrocaris Colei*. Numerous Polyzoa occur in this series, and the rest of this case and a considerable portion of the next (17), are occupied by the abundant **Brachiopoda**, several genera of which, such as *Spirifera* and *Producta*, are of great importance in the Carboniferous rocks. *Orthis*, *Chonetes*, and *Meristella* are dying out, but *Terebratula* and *Rhynchonella* for the first time become common and important. **Lamellibranchiata** of many genera fill up the rest of this case and part of the next (18), which is taken up with **Gastropods**, amongst which are specimens of *Euomphalus*, *Natica*, *Pleurotomaria*, *Loxonema*, and *Acroculia*. **Pteropods**, *Conularia* from Hook Head in Wexford, and **Cephalopods**, *Orthoceras*, *Goniatites*, and *Nautilus* from Cork, Tyrone, and Fermanagh.

Case 19 contains a set of Shells and **Cryptogamous Plants** from the Lower Carboniferous Sandstone of Ballycastle in Co. Antrim. The following are the chief genera represented in this collection:—*Sphenopteris*, *Alethopteris*, *Pecopteris*.

Case 27 contains, in the left hand side, a collection of Lower Coal Measure **Brachiopods**, including *Rhynchonella*, *Spirifera*, *Producta*, *Orthoceras*, and *Athyris*; **Lamellibranchs**—*Aviculopecten*, *Edmondia*, and *Posidonomya*; a **Cephalopod**—*Nautilus*, and one example of a Trilobite, *Phillipsia*; also fragments of **Echinoderms**—*Actinocrinus* and *Rhodocrinus*.

Cases 20–27, 42, 46, 48, 50.—Carboniferous Limestone Fossils.

This division not only spreads out over a vast area in the country, but is distinguished by its great thickness, and the abundance, variety, and admirable state of preservation of its fossils. The first case (20) contains a few specimens of **Cryptogamous Plants** from the sandy deposits of Wexford, followed by an excellent collection of **Corals** from several localities, the chief of which are situated in Limerick and Wexford. At Hook Head, in Wexford, the rocks are lying almost horizontally, and, being exposed to the action of weather along the sea-coast, the fossils stand out in relief on the surface of the beds, and can be obtained in such quantity that the locality is perhaps the best in Ireland for fossils of this age.

The corals are for the most part of reef-building kinds, and many of them are crowded together in the position of growth, thus suggesting that an old coral reef is here exposed to view. The following are the more common genera:—*Lithostrotion* (several species), (pedestal 48), *Cyathophyllum*, *Amplexus*, *Michelinia*, *Syringopora*, *Zaphrentis*, *Chætetes* (*v.* cases 20, 46, 48, 50). Corals are followed by **Echinoderms**, of which, again, this limestone furnishes a profusion (case 21); indeed, some portions of it are actually made up of broken bits of the stems of crinoids, which, however, are rarely found sufficiently perfect to warrant specific identification. Where the head of the "sea lily" is preserved, as in numerous cases displayed here, identification is easy, and the following genera are peculiarly abundant:—*Actinocrinus*, *Platycrinus*, *Poteriocrinus*, *Palæchinus*, *Archæocidaris* (*Homotæchus*), and *Pentremites*. The rest of the case is taken up with some fine examples of Annelides.

The beginning of case 22 is taken up with **Trilobites**, the last survivors of this order known in Britain. There are but four genera left, *Griffithides*, *Phillipsia*, *Proetus*, *Brachymetopus*, which have been obtained from localities in counties Donegal, Tyrone, Dublin, Kildare, Limerick, and Wexford. Polyzoa are plentifully represented in this case, which also contains an important series of **Brachiopods**, continued in cases 23 and 24, and including the following abundant genera:—*Producta*, *Spirifera*, *Chonetes*, *Meristella*, *Athyris*, *Nucleospira*, *Discina*, *Orthis*, *Lingula*, *Terebratula*, *Rhynchonella*, and *Streptorhynchus*.

Amongst the **Lamellibranchs**, which are placed in case 25, the following genera are confined to the Carboniferous system:—*Edmondia*, *Cardiomorpha*, *Sanguinolites*, and *Pleurorhynchus*; but many other genera are of great abundance and importance, as for instance:—*Aviculopecten*, *Avicula*, *Pinna*, *Inoceramus*, *Posidonomya*, *Axinus*, and *Modiola*. A few **Heteropods**—*Bellerophon*—of several species, fill up the remainder of this case.

The left hand two-thirds of case 26 is taken up with the collection of **Gastropods**, including such genera as *Murchisonia*, *Macrocheilus*, *Euomphalus*, *Pleurotomaria*, *Natica*, *Loxonema*, *Platyschisma*, *Acroculia*, *Phanerotinus* (case 50) and several other genera for the most part extinct at the present day, or subgenera presenting many points of difference from their nearest living relatives. The Gastropods are followed by the **Cephalopods**, such as *Nautilus*, *Orthoceras* (pedestal 42), *Piloceras*, *Temnocheilus*, *Cyrtoceras*, *Gomphoceras*; of such Palæozoic types as these the Carboniferous Limestone Epoch witnessed the last grand development, while *Goniatites* marks the incoming of forms belonging to the *Ammonite* type which was to be predominant in the Mesozoic Period. Most of these specimens, and others which occupy part of case 27, are from localities in Limerick, but the rest have been obtained from Dublin, Derry, Tyrone, &c. This case concludes with specimens of teeth, and palates of many genera of **Fish**, chiefly belonging to the order of Elasmo-

branchs, to which the existing Sharks, Rays, and Dogfishes belong. The following genera are of importance:—*Cladodus*, *Cochliodus*, *Gyracanthus*, *Helodus*, *Orodus*, *Petalodus*, *Psammodus*, *Psephodus*; *Palæoniscus* belongs to the Ganoids.

Cases 28–33, 38, 41, 43, 44, 46, 50.—Lower Carboniferous and Coal Measure Fossils.

Case 28 contains fossils from Coal-bearing rocks which are situated below the level of the Coal Measures proper; the beds called the Shale and Flagstone Series, which correspond in position with the Yoredale Beds and Millstone Grit of the English coalfields. Specimens of fossil plants from these beds in the Leinster and Tipperary fields are also placed here, and some from other fields, as well as Brachiopods and Lamellibranchs from Dublin and Meath. Fish from the same area are shown in case 28; the remains consist of bones, teeth, and scales—the best examples being derived from localities in Cork and Kerry, whence come the entire skeletons of *Cœlacanthus* and portions of *Holoptychius*.

Fossils from the true Coal Measures are placed in the set of cases beginning with 29, which, with part of 30 and 50, is devoted to plants. The following are characteristic and well-preserved plants:—*Lepidodendron*, *Sigillaria*, and *Stigmaria*, whose nearest living analogues are the Lycopods or club-mosses, *Calamites* now represented only by dwarf specimens of Equisetums or Horsetails; herbaceous ferns and tree-ferns such as *Asterophyllites*, and coniferous trees.

The Lowest Coal Measures frequently contain marine fossils (30), which are related to those found in the Carboniferous Limestone. Such are the **Polyzoa** *Fenestella*, *Cladochonus*, *Glauconome*; the **Echinoderms** *Actinocrinus*, *Cyathocrinus*; and the **Crustacea** *Belinurus*, of which *three* species are shown. These fossils have been obtained from Dublin, Limerick, and Queen's County. The thinly represented **Brachiopods** of these beds are to the left hand in case 31, and include *Lingula*, *Producta*, *Spirifera*, *Athyris*, *Rhynchonella*, and *Chonetes*, followed by a large number of **Lamellibranchs**, amongst which the following genera seem to be confined to marine areas—*Myacites*, *Lunulicardium*, *Myalina*, *Axinus*, *Edmondia*, *Aviculopecten*, *Posidonomya*, while *Unio* and *Anthracosia* inhabited fresh water and some few genera lived in brackish, fresh, or salt water indifferently. A few tracks attributed to Mollusca are shown in the pedestals and cases 43, 44, 46. Case 32 contains **Cephalopods**, *Goniatites*, *Nautilus*, and *Orthoceras*; **Heteropods**, *Bellerophon*; and **Gastropods**, *Loxonema*, *Murchisonia*, and *Macrocheilus*, from various Coal Measures throughout the country, with a small collection from Derry and Limerick.

A fine collection of fossil **Fish** from Jarrow Colliery in Kilkenny is placed in case 33. Some of the specimens are entire skeletons, referred to *Cœlacanthus* and *Rhizodus*, while some are

undescribed species, which are probably new. The remains of a small fish, probably *Amblypterus*, will be found in case 38.

This case also contains a number of **Labyrinthodont** skeletons from Jarrow, amongst which an almost perfect skeleton of *Urocordylus Wandesfordi* is conspicuous; *Ophiderpeton Brownriggi* is also represented. The larger of these forms probably measured 7 or 8 feet in length, but many of them were very much smaller. In case 41 are other remains of Labyrinthodonts including the heads of *Loxomma Almanni*, *Ichthyerpeton Bradleyæ*, and *Anthracosaurus Russelli*, and the almost complete skeletons of *Keraterpeton Galvani*; the specimen of this last species described by Professor Huxley, together with *type* specimens of Fish, Amphibia and other Coal Measure fossils are removed to the *special collection of type fossils* placed in the Palæontological room in the annexe.

Case 34.—Permian Fossils.

The comparatively few fossils which have been collected from the Irish Permian rocks are placed in the front part of case 34. They comprise the Coral *Favosites*, Polyzoa, **Brachiopoda**, such as *Producta horrida*, **Lamellibranchs**, like *Bakewellia*, *Mytilus*, *Schizodus*, and the **Gastropods**, *Turbo* and *Rissoa*, most of which are stunted and dwarfed by the unfavourable conditions under which they lived, while they are poor in numbers both of individuals and species.

Case 34.—Triassic Fossils.

The Triassic fossils are also very scarce and comprise a few relics of **Plants**, *Equisetites* and *Lepidostrobus* (?), **Crustacea** mostly such as lived in lakes like *Estheria*, and **Fish**, several perfect specimens of *Dictyopyge* (*Palæoniscus*) *catoptera*.

Case 34.—Rhætic Fossils.

The Rhætic fossils in the same case are such as lived in brackish water, and indicate that the sea was finding its way into the Triassic lakes and lagoons. The fossils are fairly plentiful but do not present any great number of species, the most abundant being such forms as *Cardium rhæticum*, *Avicula*, *Astarte*, and *Pecten valoniensis*. In addition to **Lamellibranchs**, scales of **Fish** are abundant, amongst the genera being *Gyrolepis* and *Acrodus*. All these fossils come from the North of Ireland, chiefly from Antrim, Derry, Down, and Tyrone, where alone these and the succeeding Mesozoic rocks occur.

Cases 34 and 35.—Liassic Fossils

The right-hand portion of case 34 and the whole of 35 contains fossils from the Lower Lias of the north of the country. The following zones appear to be represented, those of *Ammonites*

planorbis, *A. angulatus*, *A. Bucklandi*, and possibly *A margaritatus*. **Corals** are represented by *Montlivaltia*, **Echinoderms** by *Pentacrinus*, *Hemipedina*, and *Diadema*, Annelides by *Serpula lævis*, and **Brachiopods** by *Lingula* and *Terebratula*. The **Lamellibranchs** include *Lima*, *Pecten*, *Inoceramus*, *Pinna*, *Modiola*, *Hippopodium*, *Unicardium*, *Cucullæa*, *Cardinia*, *Myacites*, *Panopæa*, and *Goniomya*, the **Gastropods**, *Turritella*, *Pleurotomaria*, and *Chemnitzia*, and the **Cephalopods** chiefly *Ammonites* like *A. intermedius*, *A. planorbis*, *A. Johnstoni* (*v.* case 46), and *Belemnites* such as *B. acutus* and *B. abbreviatus*.

Case 36.—"Upper Greensand" Fossils.

The Upper Cretaceous Rocks of Ireland are only represented by a thin band of so-called Greensand followed by the Chalk. The former is probably the equivalent of some of the zones of the Lower and Middle Chalk of England, and the latter of part of the Upper Chalk, including the zone of *Belemnitella mucronata*. The greater depths of the Chalk sea do not appear to have spread so far west as Ireland until towards the end of the Epoch, so that the deposits are of an abnormal character. The "Greensand" fossils include Annelides (*Serpula*), Corals, *Parasmilia*, **Brachiopods**, *Terebratula* and *Rhynchonella*, **Lamellibranchs**, *Pecten*, *Spondylus*, *Exogyra*, *Inoceramus*, *Gryphæa*, and **Fish**, *Lamna*, *Ptychodus*, and *Otodus*. These fossils were obtained from those localities where portions of the "Greensand" crop out from under the Chalk escarpment as at Belfast and from Carrickfergus to Larne; many of them were collected by Portlock.

Cases 36 and 37.—Chalk Fossils.

This collection includes many which originally formed part of that of Portlock, but a large number of species have since been added to it. The right-hand side of 36 contains the following, among other fossils:—**Sponges** and **Corals**, *Ventriculites*, *Scyphia*, *Coscinopora*, *Cliona*, and Paramoudras (case 52); **Echinoderms**, *Echinocorys*, *Cidaris*, *Cardiaster*, *Holaster*, and *Echinoconus*; **Brachiopods**, *Terebratula* and *Rhynchonella*.

In Case 37 the following are represented:—**Lamellibranchs**, *Astarte*, *Cardinia*, *Gryphæa*, *Inoceramus*, *Lima*, *Ostrea*, *Pecten*, *Pholadomya*, and *Spondylus*; **Gastropods**, *Pleurotomaria*, *Cerithium*, and *Turbo*; **Cephalopods**, *Nautilus*, *Ammonites* (*v.* case 51), *Baculites*, and *Belemnites*.

The right-hand end of the case contains a few fossils from a peculiar fragmental deposit which occurs between the Chalk and the Tertiary Basalt on the coast near Ballycastle. Unfortunately the state of preservation of these fossils is not all that could be desired, as the nature and age of the deposit are unique in Britain. They include Annelides and **Echinodermata**—*Cidaris* and

Pseudodiadema; **Brachiopods**—*Terebratula, Crania,* and *Magas;* and **Lamellibranchs**, such as *Pecten quinquecostatus;* but it is more than probable the greater portion of them are merely the rolled relics of forms originally *in situ* in the higher beds of the Chalk.

Case 39.—Eocene Fossils.

Case 39 contains a collection of plant-remains from old soils, clays, and other deposits about the horizon of the pisolitic iron ores, which intervene between the Upper and Lower Basalts, especially at Glenarm and Ballypalidy. A large flora is disclosed by these deposits, comprising:—*Eucalyptus, Pinus, Quercus, Cupressites, Sequoia, MacClintockia, Platanus, Rhamnus, Alnus, Andromeda,* and plants of a reed-like character. These fossils are of great importance, as they give the only means of determining the approximate age of the Basalt flows. Mr. Starkie Gardner inclines to place the plant beds on the same horizon as the Bagshot beds of the Eocene of Southern England. Specimens of lignite from similar beds at Ballintoy, and silicified wood from various places in Antrim and Tyrone, probably of about the same age, are placed in the same case and in case 50.

Case 40.—Pleistocene Fossils.

Case 40 contains marine shells from gravels ("manure gravels") beneath the Boulder-clay of Wexford and from the sands and gravels in county Dublin. Among the principal species are the following, those marked thus * being extinct; thus † of northern habitat; and thus § of southern habitat at the present time:—*Fusus antiquus, Fusus islandicus, *F. menapii, §F. prostratus, *Nassa reticosa, †Natica affinis, *Pleurotoma lævis, †P. exarata, †Scalaria grœnlandica, §Turritella incrassata, †Astarte borealis, Cyprina islandica, §Pectunculus pilosus, Pholas crispata.*

The raised beaches of Lough Larne and Belfast Lough yield also marine shells, most of which still survive.

This case also contains Lignite from the pipe-clay deposits of Tipperary, *Turritella terebra* from the Boulder-clay of Dungiven, leaves and hazel-nuts, &c., from peat bogs in King's County, coralline-sand from Bantry Bay, and worked flints of human origin and neolithic type from gravels, supposed to be of the same age as the raised beaches, at Larne in Antrim.

Remains of Pleistocene **Mammals** are far less common in Ireland than in England, but the Mammoth, Reindeer, Horse, Bear, and other forms have been met with in the Shandon Cave, Waterford. Skeletons of the great "Irish Elk" (*Megaceros hibernicus*) have been found abundantly in the marls below the peat-bogs. Specimens will be seen in the Palæontological Gallery.

3.—FIGURED AND TYPE SPECIMENS OF FOSSILS.

List of Figured, Described, and Type Specimens of Fossils in the Collection of the Geological Survey of Ireland. Those to which the letter T is prefixed are the Type Specimens of the Species, and they are exhibited, together with other Irish Type Fossils, in a special case in the Palæontological Gallery. The rest will be found in the Geological Survey Gallery in the cases of which the number is prefixed to the name of the Fossil.

Ancient Rocks.

Register No.	—	Name.	Reference.	1 in Map.	Locality.
Case 1, .	–	Doubtful fossils?	Memoir of Geological Survey, Sheet 3, &c. (1891), pp. 22, 32.	3	Fintown, Donegal.
Case 1, .	–	Doubtful corals?	Mem., Sheet 1, &c. (1890), p. 53, pl. 1-4, . .	1	Culdaff, Donegal.

Cambrian Rocks.

Case 2, .	–	*Histioderma hibernica.* Kin., ...	Mem., Sheet 121 (1869), pp. 20, 21, figs. 4, 6, 7, .	121	Bray, Wicklow.
Case 2, .	–	*Oldhamia antiqua.* Forbes, ...	„ „ pp. 17, 19, figs. 1, 3, . .	–	„
Case 2, .	–	*Oldhamia radiata.* Forbes, ...	„ „ p. 18, fig. 2, ...	–	„
Y. 318, . .	T.	*Pucksia M'Henryi.* Sollas, ...	W. J. Sollas, Proc. Roy. Dub. Soc., vol. viii., part 4, p. 297, figs. 1–6.	112	Puck's Rocks, Howth, Dublin.

N. 3861,	T.	*Actinocrinus Wynnei.* Baily,	Mem., Sheet 145 (1860), p. 10, fig. 1,	145	Knocknagoogh, Tipperary.
N. 4031,	T.	„ „ „	„ „ „	–	„ „
N. 2028,	T.	„ „ „	„ „ „	–	„ „
N. 2862,	T.	„ „ „	„ „ „	–	„ „
N. 4925,	T.	*Aptychopsis subquadrata.* Jones,	T. R. Jones. Monogr. Brit. Palæozoic Phyllopoda (Palæont. Soc.), pt. ii. (1892), p. 110, pl. xv., fig. 20.	135	Cloncannon, „
—	–	*Atrypa*? (*Obolella*?)	Mem., Sheet 133 (1862), p. 15, fig. 8,	133	Kilnacreagh, Clare.
H. 2862, Case 6.	–	*Ceratiocaris*, sp.,	„ „ p. 13, fig. 5,	144	Hollyford, Tipperary.
Case 7,	–	*Crania catenulata.* Salt,	„ 119 (35 N.E., 1858) p. 9, fig. 3,	119	Chair of Kildare.
H. 1159, Case 8.	–	*Ctenodonta*, sp.,	„ 133 (1862), p. 15. fig. 9,	133	Trough, Clare.
N. 4925,	T.	(*Cucullella*) *angulata*,	Mem., Sheet 135 (1860), p. 12, fig. 4,	135	Cloncannon, Tipperary.
		Aptychopsis „ Baily,	T. R. Jones. Monogr. Brit. Palæozoic Phyllopoda (Palæont. Soc.), p. ii. (1892), p. 110, pl. xv., fig. 19.		
H. 1207, Case 3.	–	(*Didymograptus*) *Forchammeri*,	Mem., Sheet 133 (1862), p. 14, fig. 6,	133	Ballycar, Clare.
		Dicellograptus „ Geinitz,	W. H. Baily. Jour. Geol. Soc. Dub., vol. ix. (1862), p. 300, pl. iv.		
H. 2300, Case 3.	–	(*Didymograptus*) *hamatus*),	Mem., Sheet 133 (186), p. 14, fig. 7,	135	Borrisnoe, Tipperary.
		Cyrtograptus „ Baily,	W. H. Baily. Jour. Geol. Soc. Dub., vol. ix. (1862), p. 300, pl. iv.		
Case 3,	–	*Diplograptus foliaceus.* Murch.,	Mem., Sheet 133 (1862), p. 11, fig. 2 d, e,	133	Belvoir, Clare.
			W. H. Baily. Jour. Geol. Soc. Dub., vol. ix. (1892), p. 300, pl. iv.		
Case 3,	–	*Diplograptus mucronatus.* Hall,	Mem., Sheet 133 (1862), p. 11, fig. 2, f, g, h,	133	„
			W. H. Baily. Jour. Geol. Soc. Dub., vol. ix. (1862), p.300, pl. iv.		
Case 3,	–	(*Diplograptus scalariformis*), *Climacograptus scalaris.* Linn.	Mem., Sheet 133 (1862), p. 11, fig. 2, a, b, c,	„	„

FIGURED AND TYPE SPECIMENS—*continued.*

Register No.	—	Name.	Reference.	1 in Map.	Locality.
U. 213,	T.	*Euomphalus tubæformis.* Baily,	Mem., Sheet 119 (35 N.E., 1858), pp. 9, 10, fig. 6,	119	Chair of Kildare.
—	-	Fish scale,	„ 133 (1862), p. 15, fig. 11,	-	Cloncannon, Tipperary.
Case 3,	-	(*Graptolites*) *gracilis*,	„ „ p. 12, fig. 3,	133	Belvoir, Clare.
		Cœnograptus „ Hall.	W. H. Baily. Jour. Geol. Soc. Dub., vol. ix. (1862), p. 300, pl. iv.		
Case 4,	-	(*Graptolites*) *gradatus*,	Mem., Sheet 49 (1871), p. 23, pl. ii., fig. 2,	49	Tieveshilly, Down.
		Monograptus gregarius. Lapw.			
Case 4,	-	(*Graptolites plumosus*),	„ „ p. 23, pl. ii., fig. 1,	49	„
		Monograptus exiguus. Nich.			
—	-	*Olenus.* Sp.,	„ 133 (1862), p. 10, fig. 1,	133	Ballyvorgal, Clare.
M. 4059,	T.	*Orthis bailyana.* Dav.,	Monogr. Brit. Silurian Brachiopoda (Palæont. Soc.), vol. iii., p. 223, pl. xxix., figs. 19, 20.	170	Tagoat, Wexford.
N. 3839, Case 9.	-	*Orthoceras elongato-cinctum.* Portl.,	Mem., Sheet 145 (1860), p. 11, fig. 3,	145	Gortnaskehy, Tipperary.
S. 1441,	T.	*Palæasterina Kinahani.* Baily,	„ 169 (1879), p. 59, fig. 6,	169	Bannow, Wexford.
N. 3936, N. 3941, N. 3914, Case 11.	-	*Petraia* (*Du Noyeri*),	„ 143 (1860), p. 11, fig. 1,	143	Ballycar, Clare.
		„ *elongata.* Phill.			
N. 3871.	T.	*Pleurorhynchus calcis.* Baily,	„ 145 (1860), p. 11, fig. 2,	145	Reafada, Tipperary.
			„ 133 (1862), p. 15, fig. 10,	133	
—	-	Tracks,	„ 135 (1860), p. 12, fig. 3,	135	Glenmore, „
H. 4024, Case 5.	-	*Triarthrus Becki.* Green,	„ 158 (1882), p. 40, fig. 1,	158	Enniscorthy, Wexford.
Y. 344,	T.	*Trochus fucatus.* Baily,	„ 119 (35 N.E., 1858), p. 9, fig. 4,	119	Chair of Kildare.
Y. 345, Case 8.		*Turbo rupestris.* Eichw,	„ „ „ p. 10, fig. 5,	119	„

Old Red Sandstone.

Y 346, Case 14.	–	(*Adiantites hibernicus*), *Palæopteris hibernica*. Forbes.	Mem., Sheet 147 (1861), p. 14, fig. 1,	147	Kiltorcan, Kilkenny.
F. 1402, Case 15.	–	*Anodonta Jukesii*. Forbes,	„ „ p. 16, fig. 3,	„	„
H. 2674, Case 15.	–	*Coccosteus*, &c.,	„ „ p. 17, fig. 4,	„	„
U. 215,	T.	*Sphenopteris Hookeri*. Baily,	Rep. Brit. Assoc., 1859, trans. of Sections, p. 98, Mem., Sheet 147 (1861), p. 14, fig. 2.	„	„

Carboniferous Rocks.

G. 581, Case 16.	–	*Actinocrinus triacontadactylus*. Miller,	Mem., Sheet 192 (1864), p. 24, fig. 11,	192	Shehymore, Cork.
E. 3691, Case 16.	–	*Adelocrinus hystrix*. Phill.,	„ „ p. 25, fig. 12,	„	Mishells, „
P. 3816,	T.	*Archæocidaris stellifera*. Baily,	„ 70 (1877), p. 18, fig. 1,	70	Dundalk, Louth.
G. 2345, Case 16.	–	*Athyris*, sp.,	„ 192 (1864), p. 21, fig. 4,	192	Reenydonegan, Cork.
Y 347, Case 17.	–	*Axinus*, sp.,	„ „ p. 23, fig. 9,	192	Mohana, Cork.
U. 212,	T.	*Belinurus arcuatus*. Baily,	Mem., Sheet 137 (1859), p. 13, fig. 4, „ 127, &c. (1881), p. 24, fig. 8 W. H. Baily, Ann. Mag. Nat. Hist., ser. 3, vol. xi. (1863), p. 157, pl. v.	137	Bilboa, Queen's Co.
N. 1202,	T.	*Belinurus Reginæ*. Baily,	Mem., Sheet 137 (1859), p. 13, fig. 3, „ 127, &c. (1881), p. 24, fig. 7. Ann. Mag. Nat. Hist., ser. 3, vol. xi. (1863), p. 157, pl. v.	„	„ „

FIGURED AND TYPE SPECIMENS—*continued.*

Register No.	—	Name.	Reference.	1 in Map.	Locality.
Y. 348, Case 21.	-	*Brachymetopus McCoyi.* Portl., . .	H. Woodward. Monogr. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4, p. 52, pl. viii., fig. 11.	-	Ballysteen, Limerick.
N. 3154, .	T.	*Corynepteris stellata.* Baily, ...	Mem., Sheet 142 (1860), p. 17, fig. 8, . . .	142	Glenn, „
G. 512, Case 17.	-	*Cucullæa Griffithi.* Salt, ...	„ 192 (1864), p. 22, fig. 5, . . .	192	Mohanagh, Cork.
E. 3833, Case 18.	-	*Curtonotus centralis.* Salt, ...	„ 187 (1864), p. 28, fig. 6, . . .	187	Enniskeen, „
E. 4283, Case 18.	-	*Curtonotus elegans.* Salt, ...	„ „ „ . . .	„	Lehenagh, „
Y. 349, Case 18.	-	*Curtonotus elongatus.* Salt, ...	„ „ „ . . .	„	Old Head of Kinsale. Cork.
E. 1686, Case 18.	-	*Curtonotus rotundatus.* Salt, ...	„ „ „ . . .		Queenstown, Cork.
N. 646, Case 16.	-	*Cyathophyllum celticum.* Lonsd., . . .	„ „ p. 24, fig. 4, . . .	„	Old Head of Kinsale, Cork
G. 2208, Case 17.	-	*Cyrtina heteroclita.* Def., ...	„ 192 (1864), p. 21, fig. 2, . . .	192	Reenydonegan, Cork.
E. 4349, Case 16.	-	*Filicites lineatus.* Baily, ...	„ 187 (1864), p. 20, fig. 2, . . .	187	Dunworly Bay,
Case 28, .	-	Fish scales, ...	„ 142 (1860), p. 19, fig. 10, . . .	142	Rosscliff, Clare.
C. 817, C. 833, C. 845, Case 32,	-	*Goniatites crenistria.* Phill., ...	„ „ p. 12, fig. 2, . . .	„	Foynes Island, Cork.

N. 4862, Case 21.	–	*Griffithides globiceps.* Phill.,	H. Woodward. Monogr. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4, p. 29, pl. vi., fig. 1. T. Oldham. Journ. Geol. Soc., Dublin, vol. iii., (1849), p. 188, pl. 2.	111	Millicent, Kildare.
Y. 350, Case 21.	–	*Griffithides platiceps.* Portl.,	H. Woodward. Monogr. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4. p. 34, pl. vi., fig. 13.	26	Cookstown, Tyrone.
B. 2866,	T.	*Keraterpeton Galvani.* Huxley,	Trans. Roy. Irish Acad., vol. xxiv. (1871), p. 354, pl. 19.	137	Jarrow, Kilkenny.
K. 878, Case 18.	–	(*Leda*) *attenuata,* Nuculana „ Flemg.	Mem., Sheet 127 (1862), p. 9, fig. 2,	127	Bunnow, King's Co.
C. 846,	T.	*Loxonema Galvani.* Baily,	„ 142 (1860), p. 13, fig. 5,	142	Foynes Island, Limerick.
C. 2231,	T.	*Loxonema minutissima.* Baily,	„ „ p. 15, fig. 7,	„	Knockabooley, „
U. 210,	T.	*Lunulicardium Footi.* Baily,	„ „ p. 19, fig. 9,	„	Rosscliff, Clare.
C. 827,	T.	*Macrocheilus inflatus.* Baily,	„ „ p. 14, fig. 6,	„	Foynes Island, Limerick.
U. 209,	T.	*Myalina foynesiana.* Baily,	„ „ p. 13, fig. 4,	„	„ „
G. 256, Case 18.	–	*Nucula tenuiarata.* Sandberger,	„ 192 (1864), p. 23, fig. 6,	192	Mohanagh, Cork.
G. 358, Case 18.	–	*Nucula,* sp.,	„ „ p. 23, fig. 7,	„	Lakelands, „
G. 339, Case 18.	–	*Nucula,* sp.,	„ „ p. 23, fig. 8,	„	Sheperton, „
K. 657, Case 26.	–	*Orodus ramosus.* Ag.,	„ 127 (1862), p. 12, fig. 3,	127	Mountrath, Queen's Co.
C. 816,	T.	*Orthoceras minimum.* Baily,	„ 142 (1860), p. 13, fig. 3,	142	Foynes Island, Limerick.
G. 749, Case 18.	–	*Orthoceras undulatum.* Sow.,	„ 192 (1864), p. 23, fig. 10,	192	Mohanagh, Cork.

FIGURED AND TYPE SPECIMENS—*continued.*

Register No.	—	Name.	Reference.	1 in Map.	Locality.
U. 211,	T.	*Pecopteris Edgei.* Baily,	Mem., Sheet 137 (1859), p. 14, fig. 5. „ 127, &c. (1881), p. 25, fig. 9.	137	Jarrow, Kilkenny.
U. 213,	T.	*Pentremites (Orophocrinus) prælongus.* Baily,	W. H. Baily. Proc. Roy. Dub. Soc., N.S., vol. v. (1886, 7), p. 31, pl. i.	102	St. Doolagh's & Raheny, Dublin.
T. 2001, T. 2002, T. 2003, T. 2005, T. 2006, T. 2008, Case 21,	–	*Phillipsia Colei.* M'Coy,	H. Woodward. Mon. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4, p. 16, pl. ii., figs. 1–6.	32	Ballintra, Donegal.
Y. 351, Case 21.	–	*Phillipsia gemmulifera.* Phill.,	H. Woodward. Mon. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4, p. 17, pl. iii., fig. 2.	102	St. Doolagh's, Dublin.
Y. 352, Case 21.	–	*Phillipsia truncatula.* Phill.,	H. Woodward. Mon. Brit. Carboniferous Trilobites (Palæont. Soc.), 1883-4, p. 21, pl. iii., fig. 9.	179	Hook Head, Wexford.
C. 4386, Case 16.	–	*Platycrinites lævis?* Miller,	Mem., Sheet 192 (1864), p. 26, fig. 13,	192	Mathew's Rock, Cork.
E. 2875, Case 16.	–	*Pleurodictyum problematicum.* Goldf.,	„ 187 (1864), p. 25, fig. 5,	187	Mellifontstown, „
G. 2385, Case 17.	–	*Producta*, sp.,	„ 192 (1864), p. 21, fig. 3,	192	Reenydonegan, „
E. 4003, Case 16.	–	*Protaster*, sp.,	„ 187 (1864), p. 30, fig. 7,	187	Concamore, Clonakilty, Cork.

Y. 353, Case 14,	-	*Sagenaria veltheimiana*. Sternb.,	„ „	p. 22, fig. 3, ... 192 (1864), p. 20, fig. 1.	187	Tallow Bridge, Cork.
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I. 2134, .	T.	*Pinus Plutonis*. Baily, ...	Quart. Journ. Geol. Soc., vol. xxv., p. 360, pl. xv., .	„	Ballypalidy, Antrim.
I. 2115.	T.	(*Sequoia Du Noyeri*). Baily, *Cryptomeria Sternbergi*. Goepp. . . .	Quart. Journ. Geol. Soc. vol. xxv., p. 361, pl. xv., .	„	„ „

PART IV.

THE ILLUSTRATIONS.

These comprise the following classes:—1. A series of 41 drawings by the late G. V. Du Noyer, placed on the west side and two ends of the room; a few drawings by W. H. Baily are placed in this series. 2. A set of 5 enlarged photographs of views in Antrim, taken and presented by Dr. Tempest Anderson, placed between the windows on the east side of the gallery. 3. A set of 44 photographs, kindly presented by the Belfast Naturalists' Field Club, and collected by Miss M. K. Andrews; the photographs were taken by Miss Andrews, Miss Tate, Mr. R. Welch, and Mr. J. J. Stelfox. 4. A set of 47 photographs illustrating the geology of Ulster, taken and presented by Mr. R. Welch. 5. Geological maps, on the one inch scale as issued by the Geological Survey, to illustrate the rocks displayed in the wall-cases. 6. Horizontal and vertical sections of the rocks and mining plans and sections. 7. Small drawings in the wall cases.

With the exception of the last three, these are numbered in a continuous series from the south end of the room by the west to the north and east.

Drawings and Photographs.

Structural Phenomena.—"Dead Cow Cliff" in Kerry (3) shows *contorted* and *faulted* rocks of Old Red Sandstone age. The Peak in Magillicuddy's Reeks (16) is an excellent example of the way in which the *contortion* and *cleavage* of rock masses affect the type of mountain peaks carved out of them; 5, 19, 22, and 46 illustrate *contortion* still further, one example (22) being taken from a locality near Rush in Dublin. Ancient *dykes* of felsite in the Old Red Sandstone and associated volcanic rocks are shown in 8 and 9, and the familiar section at Killiney showing the *granite* intruding into Silurian schists is depicted in 21. An admirable example of the *unconformable relationship* of the Old Red Sandstone to Silurian rocks occurs at Waterford, and is shown in 17. The *chert* layers or nodules which are so frequently to be seen in the Carboniferous Limestone are drawn in 7, 20, 33, and 47, the first of this set being contorted.

The rocks of the **Basalt plateaux** lend themselves readily to pictorial illustration. General sections showing the basalt overlying the chalk, sometimes with a flint gravel between, and itself overlain by gravel or boulder-clay, will be seen in 13, 23, 24, 27, and 32, and in the photographs 59, 69, 80, and 83; 83 also illustrates the formation of *landslips* when the heavy basalt is undermined by springs dissolving or soaking the soluble or soft rocks underneath. The bands of *iron-ore* between the basalt sheets are shown in 48, at Kilwaughter, where the ore has been mined. 28, 29, 43, and 44, and the photographs 58, 60, 68,

77, 89, and 90, illustrate *dykes* of basalt penetrating various strata, including Trias, Greensand, Chalk, and Basalt; some of these dykes show the columns at right angles to the edge of the dyke (77). "*Necks*" of basalt, the site of old volcanoes, are illustrated by 71 and 74, while 63 shows the great intrusive *sill* or laccolite of Fair Head which is injected into Carboniferous rocks. Many of those just mentioned, as well as 25, 29, 31, 32, 52, 53, 56, 61, 64, 67, and 72, show the *columnar* or prismatic jointing of the basalt, and 18 is a good example of the same rock exfoliating into *spheres*, a very characteristic mode of weathering. The general appearance of basalt *outcrops*, weathering into step-like cliffs with sloping terraces between, is admirably rendered in 34, and the grand *coast cliffs* of basalt by 75.

Glacial phenomena again can be well illustrated. D. 35 shows a section of boulder-clay at Sutton on Howth, and the top of several other sections is formed of the same deposit (73). Large *boulders* in Wexford (36), a *perched block* near Killarney (39), one in Ulster (84), and a *Rocking-stone* in Island Magee (45) (probably the same as the photograph, 79), give a good idea of the massive materials carried by ice for great distances. The graceful outlines and sweeping curves of groups of *eskers* are well shown in 37 and 38, while the Devil's Punch-Bowl near Killarney (4) is an example of a lake dammed by a *glacial moraine*.

Coming to **modern phenomena**, the power of marine *denudation* in carving away a coast is shown by the *sea stacks*, chiefly from the northern coast, in 41, 54, 55, 59, 62, 64, 65, 66, and by one of the photographs (70), which depicts a pump now surrounded by the sea, but originally erected in 1824 or 1825 to pump water from a sandstone quarry, which was then at some distance from the sea. A valley cut through the Tertiary Basalts is shown in 74. The sea stacks in 57 are raised far beyond the reach of the sea, and are connected in date with one of the raised beaches on the Antrim coast. The rest of the drawings and photographs are devoted to illustrating the cliffs or outlines due to different types of rocks, *Silurian* and more ancient rocks, 70, 74, 82, 85, 86, 87, and 88; *Old Red Sandstone*, 6, 10, 14, 15, and 79; and *Carboniferous rocks*, 70, 71, 81, 88, 91, and 92.

The Maps.

The upper part of each wall-case contains one or two maps made up from the sheets of the 1-inch Geological Survey map, to represent some striking or important area of igneous rocks, which is illustrated by the collection of rocks placed below. The following is a list of the maps:—

A. The northern and southern part of the great Leinster Granite and its bordering rocks.
B. The area of Carlingford and Clogher Head. Dublin, Lambay and Portraine.
C. Mid-Mayo, Achill Island, Clew Bay, and the Ox Mountains.
D. South Mayo and Galway (the continuation of C to the South).

E. The northern part of the area of Granitic and Foliated Rocks in Donegal.
F. Coloured table of the succession of Strata in Antrim.
The Volcanic Plateau of Antrim.
G. The Igneous Rocks of the Waterford Coast.
The Igneous Tract of Killarney and Lough Guitane.
The Limerick Carboniferous Volcanic Tract.

The Sections and Plans.

The **Horizontal Sections** represent what would be seen if a deep canal were cut right through the country in such a direction as to show best the structure and mutual relations of its component rocks. The **Vertical Sections** show what would be seen if a deep shaft were sunk through the rocks at right angles to their surface. The districts chosen are remarkable for the peculiar structure and relations of the rocks or for their economic value. The following is a list of them :—

Horizontal Sections.

1, Sheet 24.—(*a.*) From the entrance of Carlingford Lough to Newcastle, across Silurian rocks, the Mourne Granite, and its offshoots and dykes.

(*b.*) From Killinchy across Scrabo Hill to Cultra, showing Silurian, Carboniferous, Permian, and Triassic rocks, and the Tertiary Basalt.

2, Sheet 29.—From Carrickfergus to Fair Head and Rathlin Island, showing the relation of the Basalts to Foliated, Old Red, Carboniferous, Triassic, and Cretaceous rocks.

26, Sheet 34.—Across Donegal from the Fin Valley by Errigal Mountain to Bloody Foreland. Foliated and Plutonic rocks.

30, Sheet 26.—(*a.*) From Killary Harbour to Clew Bay. Foliated, Silurian, and Carboniferous rocks.

(*b.*) From Moher Lough to Lough Mask. Silurian rocks.

50, Sheet 10.—Across the Slieve Ardagh Coalfield, Tipperary.

51, Sheet 14.—Across Howth and parts of Dublin, showing Cambrian, Silurian, Carboniferous, and Intrusive rocks.

Vertical Sections.

42.—25 Shafts in the Castlecomer Coalfield.

Plans.

11.—The Ovoca Mines, Co. Wicklow.

Small Drawings, &c.

At the sides of the wall-cases will be found a series of small drawings, chiefly from illustrations published in the Survey Memoirs, some by Sir A. Geikie and the rest by Mr. M^c^Henry, intended to illustrate still further numerous points connected with the structure, scenery, and economic utility of the rocks displayed in the cases themselves. An attempt has been made in one of them to show in a diagrammatic fashion the age, character, composition, and relations of the igneous rocks of Munster.

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